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PROGRESS REPORTS

Report by the Working Group I

(Prepared by the Co-Chairs of Working Group I)

(Submitted by the Secretary of the IPCC)

[1] This revised version includes, as an annex, the draft proceeding of the co-sponsored WCRP-IPCC workshop on Earth System High Impact Events, Tipping Points and their Consequences.

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PROGRESS REPORTS

Report by the Working Group I

This report describes the activities undertaken by the Working Group I (WGI) since the last update presented during the Sixty-third Session of the IPCC in October 2025.

1. Establishment of the TSU

WGI TSU is currently hiring an AI Officer. The selected candidate will play a pivotal role in developing, implementing, and optimizing artificial intelligence solutions to support the Authors, the TSU and the WGI Bureau during the preparation of the IPCC reports. This will include, for example, assessing tools to support specific activities ((systematic) literature reviews, processing of review comments, text refinement, translation…) but also developing best practices and guidelines regarding ethical and legal questions raised by the use of AI-based tools.

WGI TSU has opened a position for an additional Science Officer with expertise in the terrestrial biosphere and/or carbon cycle (https://www.ipcc.ch/2026/02/17/science-officer-ipcc-wg1-tsu/) in order to complete the expertise covered by the existing science team.

The French and the Chinese TSU work together at supporting the WGI Bureau. Weekly TSU meetings are organized to take stock and plan the work ahead.

2. Special Report on Climate Change and Cities

Since October 2025, WGI Bureau and TSU have contributed, under the operational lead of WGII, to:

- ✓ The review of the First Order Draft of the Report;
- ✓ The preparation and the holding of the Third Lead Author Meeting which took place in Oslo, Norway on 12-16 January 2026;
- ✓ The first steps of the development of the First Order Drafts of the Technical Summary and of the Summary for Policymakers of the Report.

3. Working Group I contribution to the IPCC Seventh Assessment Report

Holding of the First Joint Lead Author Meeting

On the invitation of the French Government, the First joint Lead Author Meeting was held in Paris on 1-5 December 2025 and gathered WGI-II-III experts. A total of 650 participants attended the meeting. The operational preparation of the event was led by WGI TSU.

The week allowed for a variety of meeting types, combining activities within and between working groups. The schedule included:

- ✓ Plenary sessions and breakout group discussions bringing together experts from the different Working Groups;
- ✓ Plenary sessions and breakout group discussions within each working group;
- ✓ Informal discussion and training sessions;
- ✓ A team-building session.

By all accounts, this event was a success, fostering high-quality exchanges in a highly collaborative atmosphere among the authors and between the Working Groups. These exchanges will continue throughout the cycle and contribute to the quality of the reports.

Joint Zero Order Draft

On 6 February, the Zero Order Draft of the ten chapters and one Annex of the WGI Report was submitted to the WGI TSU for compilation ahead of the informal review. On 23 February, invited experts and all WGI, WGII and WGIII authors will be provided with the drafts for their feedback during an informal commenting period of 8 weeks. WGI Bureau Members and Authors will also be able to access and comment the WGII and WGIII Zero Order Drafts that will be available at the same time. The review will close on 2 April.

Second Lead Author Meeting

The Second Lead Author Meeting will be held 20–24 April 2026 in Santiago, Chile. The kind invitation of the Government of Chile, through Pontificia Universidad Católica de Chile is gratefully acknowledged. Invitations were sent out at the end of January to all participants and efforts are underway to support the logistical arrangements and the programme planning.

4. Co-sponsored Workshop on High-Impact Events and Earth System Tipping Points

WGI was in charge of the operational lead of the World Climate Research Programme (WCRP) and the Intergovernmental Panel on Climate Change (IPCC) co-sponsored a workshop that was held in Paris from 26 to 28 November 2025, the week before the joint IPCC First Lead Author Meeting (LAM1). The workshop brought together leading experts from across the globe and from multiple disciplines to build consensus and address urgent questions related to high impact events, tipping points and their consequences.

The three-day meeting evaluated and advanced our ability to assess the risk of Earth System high impact events, tipping points, and their consequences. It provided selected IPCC authors and Bureau members with an invaluable opportunity to exchange with a broad group of leading experts, to benefit from community insights into these complex questions and allowed scientific discussions, networking and bridge-building across IPCC Working Group domains.

The Workshop Proceedings will be available on-line in May 2026. The pre-production version of the workshop report is attached to this document as Annex I.

5. Expert Meeting Atlas

Following Decision IPCC-LXIII-2 to approve the proposal for an Expert Meeting on Regional Climate Information & Atlas:

- ✓ The Scientific Steering Committee (SSC) was formed, including Co-Chairs and Vice Chairs from WGI and WGII;
- ✓ The SSC met three times to discuss the time and location of the meeting, its objectives and content and to discuss/select participants;
- ✓ Invitations to participants were sent out late January 2026.

The meeting, which will be hybrid, will be held in Santiago, Chile, on 27-28 April 2026, back-to-back with WGI Second Lead Author Meeting. SSC Meetings are scheduled in the coming weeks in order to define the structure of the meeting and prepare all meeting documents (background information, detailed agenda etc.).

The kind invitation of the Government of Chile, through the Faculty of Government, University of Chile is gratefully acknowledged.

ANNEX I

Co-sponsored Workshop on High-Impact Events and Earth System Tipping Points

Pre-production version of the workshop report

PRE-PRODUCTION VERSION

Proceedings from WCRP-IPCC co-sponsored workshop on "Earth system high impact events, tipping points and their consequences"

Sorbonne Université – Campus Pierre et Marie Curie, Paris, France

26-28 November 2025

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All workshop participants contributed to the report's content through their input during the meeting. The list of authors below lists those who had a leading role in drafting sections of the LAM1 summary documents, in note taking and summarizing of notes, in drafting the proceedings, providing keynote presentations or facilitating sessions.

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The workshop proceedings were prepared under the editorial leadership of G. Hansen, N. van der Wel, P.M. Abbott, T. Naish, and R. Vautard, who coordinated the drafting and compilation of the report drawing on contributions and discussions from workshop participants.

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1. Preface

The fast-warming climate raises a number of scientific challenges as it drives the Earth System into states that are unprecedented in human history. This requires an understanding of potential high-impact systemic changes or events, including those associated with “tipping points” and their cascading consequences. Due to the nonlinear dynamics of the Earth System, its response to human forcing can also be nonlinear, potentially leading to “tipping dynamics” in its components. Such changes in Earth system components and their ecosystems (e.g. ice sheets, ocean circulation, rainforests, coral reefs, permafrost, and monsoons) can greatly amplify climate risks, as they can trigger large, often irreversible shifts that have dangerous local and regional consequences. They are an additional danger to the already growing risks of heat waves, droughts, extreme sea levels, increased occurrence and intensity of several other extreme event types, all of which constitute multiple reasons for concern. However, due to lack of precedence in the recent observational record, the biophysical mechanisms at play, and the likelihood of those outcomes are poorly known, resulting in inconsistent use of terminology and emotive communication narratives, leading to confusion, and in some cases disengagement, of public and stakeholders.

Even though high-impact or abrupt events were not always framed explicitly as “tipping points”, the Intergovernmental Panel on Climate Change (IPCC) has addressed this topic since its First Assessment Report (FAR). The FAR drew attention to paleoclimate evidence and theoretical models, and introduced concepts such as “abrupt change”, “irreversibility”, and “surprises” that could occur under future warming scenarios. By the completion of the Fourth Assessment Report (AR4) in 2007, this aspect of climate change had been elevated to the Summaries for Policymakers (SPM) and thus was brought to the attention of all governments.

The Working Group (WGI) Fifth Assessment Report (AR5) addressed tipping points generally, and irreversibility specifically, while WGII AR5 highlighted the impacts and risks with increasing global warming levels, if physical systems or ecosystems experienced abrupt and irreversible changes. By the Sixth Assessment Report (AR6), tipping point behaviours and their consequences were being addressed across many chapters.

As the scientific knowledge base grew, it was recognised that global warming increases the risk of crossing threshold temperatures associated with several tipping systems. This together with growing public interest, and concern from decision makers, led the IPCC WGI to dedicate a chapter to “Abrupt changes, low-likelihood high impact events and critical thresholds, including tipping points, in the Earth system” (WGI Chapter 8) in its contribution to the Seventh Assessment Report (AR7).

In order to develop consensus and a shared approach across scientific communities, the World Climate Research Programme (WCRP) and IPCC brought together a diverse group of the world's leading scientists for a milestone workshop in Paris ahead of the AR7 joint 1st Lead Authors Meeting (LAM1). Hosted by the Institut Pierre-Simon Laplace (IPSL) at Sorbonne Université, the workshop on "Earth system high-impact events, tipping points and their consequences**",** convened experts from across disciplines—including authors from AR7 WGI Chapter 8, key authors from WGII and WGIII, IPCC Bureau members and WCRP's leadership and key experts.

WCRP is undertaking a comprehensive scientific assessment on "High Impact Events, Tipping Points in the Earth System and their Consequences", to be submitted in 2026. Key findings from its initial draft contributed to the outcomes of the workshop and the workshop proceedings. With scientific knowledge in this area expanding rapidly, WCRP and the IPCC recognized a need to clarify concepts, homogenize definitions across scientific communities, assess areas of emerging evidence and key questions, and identify research gaps as a foundation for future assessments. The workshop was not intended to carry out a scientific assessment but instead aimed to set a platform with a shared understanding and provide a set of recommendations (Section 2), for the coordination and delivery of the WCRP paper and the IPCC Reports.

We want to acknowledge all the experts, the members of the IPCC Bureau, the Scientific Steering Committee and the support crew on-site for their efforts and dedication in the planning and execution of this workshop, and their support in drafting the preliminary workshop summary and recommendations document that informed the 1st Lead Author Meeting of the IPCC AR7, as well as these proceedings.

The enthusiasm and constructive attitude at the workshop and the fervent uptake of its outcomes at LAM1 are shining examples of interdisciplinary and inclusive scientific cooperation between experts and between our institutions, and evidence of the timeliness and urgency of addressing this topic.

We are deeply grateful to all participants for investing their time, energy and expertise, and for their open-mindedness and perseverance, making this unique workshop possible.

Tim Naish, WCRP JSC Chair　　Robert Vautard, IPCC WGI AR7 Co-Chair

2. Key recommendations and summary of the meeting

This section is identical with a summary report that was produced by the workshop Scientific Steering Committee (SSC) to provide preliminary recommendations for consideration by AR7 authors at the first IPCC Lead Author Meeting (LAM1), held jointly by the three Working Groups in Paris on 1–5 December 2025.

2.1 Overview

Earth system high impact events and tipping points have the potential to drive substantial, widespread and, in some cases, irreversible changes across the climate system, ecosystems, and human societies. Recognising the growing importance of these risks, the IPCC's Seventh Assessment Report (AR7) includes, for the first time, a dedicated chapter on this topic. Yet key questions have persisted regarding how tipping points should be defined, their significance for climate-risk assessment, and how evolving scientific understanding and uncertainty should be communicated to policymakers, the public, and the media.

To strengthen clarity and scientific consensus, the World Climate Research Programme (WCRP) and the Intergovernmental Panel on Climate Change (IPCC) convened a high-level workshop in Paris from 26–28 November 2025, hosted by the Institut Pierre-Simon Laplace (IPSL) at Sorbonne Université. This invitation-only meeting brought together leading scientists, including AR7 authors, to refine definitions, review emerging evidence on tipping points and threshold behaviour, identify critical knowledge gaps, and consider approaches for assessing a rapidly developing field of research.

The workshop aimed to:

- Advance scientific understanding and risk assessment of Earth system high impact events and tipping points: what we know and don't know, what's new, what's coming, what's missing, and what tools we have or should develop?
- Facilitate dialogue within the international scientific community on the implications of high impact events and tipping points for climate mitigation, adaptation, ecosystems, and sustainable development.
- Encourage collaboration among WCRP, IPCC Working Groups, and related research initiatives, with particular emphasis on Global South participation.

2.2 Concepts, definitions, and joint framework

The workshop participants discussed several key concepts and definitions for future research and AR7. An important goal was to develop a common understanding ahead of the AR7 cycle of some types of events occurring in the Earth system that have large consequences or impacts.

2.2.1 Methodology

Participants started from the IPCC definitions of four pre-selected key concepts, for which AR6 glossary entries and definitions already exist. They then examined whether, based on experience since AR6, the practical use of these concepts/definitions had led to unwanted concerns or disagreements within the scientific communities. In this case, it was asked whether a new definition could be proposed. If yes, it was asked what the consensual elements of such a new proposition would be, and what choices should be left for future consideration, for instance by IPCC authors. It was also asked whether new concepts needed to be defined to improve the common understanding. There was a series of breakout groups that allowed all participants to express their views, which were then synthesised. Plenary presentations with opportunities for feedback were made regularly before drafted recommendations were finalized.

2.2.2 Concepts that were used as starting points

The following 4 concepts were discussed: **"abrupt change"**, **"LLHI outcome"**, **"cascading impacts"** and **"tipping point"**. Here is the summary of recommendations that were given and explanations of how participants came to the conclusions.

2.2.2.1 Abrupt change

The AR6 IPCC glossary definition (IPCC, 2022)[1]

"A change in the system that is substantially faster than the typical rate of the changes in its history."

Reasons for proposed change

- The previous IPCC definition referred to historical changes, which were felt to be ambiguous, and might have a lack of data. The concept of 'typical' was also raised as being ambiguous.
- Abruptness, in the context of a forced system, is meant to describe how the response relates to a forcing and not to historical dynamics. That is, it should be defined in state-space rather than in the time-domain.
- Abrupt (in a temporal sense) can mean days to centuries depending on the system. This is especially confusing when discussing e.g., paleoclimate evidence vs. contemporary change.

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[1] IPCC (2022) Annex II: Glossary [Möller, V., van Diemen, R., Matthews, J.B.R., Méndez, C., Semenov, S., Fuglestvedt, J.S., Reisinger, A. (eds.)]. In "*Climate Change 2022: Impacts, Adaption and Vulnerability*. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Pörtner, H.-O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem, A., Rama, B. (eds.)], Cambridge University Press, Cambridge, UK and New York, USA, pp.2897-2930.

- Abruptness does not mean it is immediate (happening tomorrow). This can be demonstrated by adding examples.

Revised definition

The participants therefore recommended a new definition, which could address the above points:

Abrupt change: When the system response accelerates disproportionately to the rate of change of forcing/causes/drivers. [Forcing can include, for instance, changes in atmospheric composition, land use, human systems, etc…]

Notes, potential remaining questions, and recommendations

- There was no consensus on using 'forcing', 'causes', or 'drivers.' The argument was made that 'forcing' is more specific (e.g., emissions vs. radiative forcing, not a linear relationship) but is implicitly founded in WGI-type physical science framing. 'Causes' is more general and may be useful for cross-WG use of the definition but is less specific.
- If 'forcing' is used, a second sentence may be necessary to describe what we mean by forcing. This may be less necessary for 'drivers' or 'causes' because these terms are more widely understood.
- Either way, examples should be given to illustrate both what *is* and what *isn't* considered 'abrupt'.
- Examples could include noise-induced change, i.e., system change due to internal variability, where a response is triggered even though there is zero change in external forcing.

2.2.2.2 Tipping point

The AR6 IPCC glossary definition (IPCC, 2022)[2]

"Tipping point: A critical threshold beyond which a system reorganizes, often abruptly and/or irreversibly."

Reasons for proposed change

- The definition is too vague and confusing, and is being used in multiple, sometimes conflicting ways (including a discrepancy between natural and social sciences).
- Irreversibility is clearer if accompanied by a time scale.
- Centering the definition on a singular tipping "point" (threshold) may lead to misunderstanding (since some systems have multiple thresholds), and underrepresent the complexity of the system, which is tipping as a whole.
- Therefore, the central concept here is thought to be the "system" and its tipping dynamics, and the "tipping point" concept should refer to it as part of its dynamics.

[2] Ibid.

Revised definition

Tipping [element] / [system]: A component of the Earth system that undergoes self-reinforcing changes that are abrupt and/or not reversible on human timescales when a critical threshold is crossed.

Notes, remaining questions and recommendations

- Remaining question: The choice between 'tipping element' or 'tipping system' (some of the more recent literature seems to focus on 'tipping system' to reveal that these might not all be 'macro-elements' but could also involve 'propagating' or 'clustered' dynamics). Is this an Earth system tipping element/system or generic?
- The explanatory text should mention that some elements/systems have multiple thresholds.
- Recommendation: Additional definition should be given also for 'tipping point' (based on the revised definition of tipping system/element), and potentially 'tipping dynamics'.
- A definition of "not reversible / irreversible" is needed.
- A definition of "human timescales" would be useful (the term is also used in different IPCC chapters).
- Recommendation: Add examples to illustrate the different components of the definition.
- Connect to further related concepts such as hysteresis / multiple equilibria.
- Add a note on the spatial scales (which tipping elements / systems are considered).

2.2.2.3 Low-Likelihood High Impact Outcomes

The AR6 IPCC glossary definition (IPCC, 2022)[3]

Outcomes/events whose probability of occurrence is low or not well known (as in the context of deep uncertainty) but whose potential impacts on society and ecosystems could be high. To better inform risk assessment and decision-making, such low-likelihood outcomes are considered if they are associated with very large consequences and may therefore constitute material risks, even though those consequences do not necessarily represent the most likely outcome.

Reasons for change that showed consensus

- "Low likelihood" conveys the wrong impression that IPCC assessed the likelihood, and it is "low". Instead, we need to focus on a definition focusing on events with likelihood that is "uncertain", but where there is some certainty that these would induce high impacts.
- When applying this concept, the spatial scale of consequences or impacts could be clarified (the writing team consensus was that the scale would be "regional to global" or "large-scale", without preferring any of the two).

[3] Ibid.

Revised definition

"High Impact Potential" (HIP) events or "Potential events with high impacts": Events whose probability is not well known but whose impacts would be severely consequential on [regional to global] / [large] scales.

Notes, potential remaining questions, and recommendations

- The writing team debated the use of 'potential', 'possible' or other (e.g., "plausible", although this is weak in English compared to other languages) and chose "potential" as that could align with definitions in risk framing. The choice of language should not imply probability.
- The question of spatial scales remains unresolved and could be changed to "at a large scale", the intention is to preclude discussing local or small region scales to avoid overlap with extreme events.
- The team consensus was to start the title with "high impact" to avoid confusion with "potential" applying to impacts instead of the event.
- The "events" considered should include both rapid and slow-onset changes, such as permafrost thaw or sea level rise.
- Note the acronym is HIP events (HIPE as an acronym would be problematic for communication), hence the suggestion to have only HIP as an acronym and always write "event" separately (synchronous with HILL events prior).

2.2.2.4 Cascading impacts

The AR6 IPCC glossary definition (IPCC, 2022)[4]

Cascading impacts from extreme weather/climate events occur when an extreme hazard generates a sequence of secondary events in natural and human systems that result in physical, natural, social or economic disruption, whereby the resulting impact is significantly larger than the initial impact. Cascading impacts are complex and multi-dimensional and are associated more with the magnitude of vulnerability than with that of the hazard (modified from Pescaroli and Alexander, 2015).

Reasons for change that showed consensus

- The prior IPCC definition is too long and wordy, too specific, it should be shorter and simpler; and it should be defined in relation to different types of triggering systems, to be more general.
- These impacts can occur within the same system/place or cascade into other systems and places. Examples: sea level rise that will impact populations of low-lying areas and cause salinity intrusion into freshwater underground reservoirs; or heat/drought in multiple

[4] Ibid.

breadbaskets impacting on the food system. Local glacier loss can have an impact on water availability over large regions downstream.

Revised definition

Cascading impacts: When an event or trend leads to impacts that in turn trigger sequences of impacts across natural and/or human systems.

2.3 Cascades from Earth system HIETPs to impacts, adaptation and mitigation

Translation from phenomena to impacts in the following ways is needed:

- There is a need for developing a framework for understanding the propagation pathways by which global or regional tipping elements/systems manifest via risk chains and networks as regional impacts (including Climatic Impact-Drivers (CIDs)). It is recommended to look for case studies to build such a framework.
- CIDs are conditions such as extreme heat, heavy precipitation, or mean sea-level rise that directly affect elements of society or ecosystems (IPCC WGI AR6). It is important to note that CIDs do not comprehensively cover all drivers that could demonstrate the impacts, nor do they include rates of change.
- The focus is on tipping elements/systems that might trigger non-linear impacts and/or systemic failures in socioecological systems.
- There is a need to identify the boundaries of such socioecological systems and the underlying conditions (governance, economic development, peace) that determine their vulnerability to these impacts and, hence, the potential risks they may face.
- This translation is also necessary to ensure community participation in the Global South.

Irreversibility of intangible losses: There is a need for considering irreversible loss beyond physical assets to include intangible systems, specifically the loss of cultural heritage, traditional knowledge systems, and Indigenous ecological relationships that cannot be restored via adaptation (an example can be found in WGII AR6, TS10).

Feedback loops to mitigation and adaptation capacity: how biophysical cascades (e.g., fire-induced boreal forest dieback) function as feedback mechanisms that fundamentally compromise mitigation potential by degrading carbon sinks and limiting the feasibility of nature-based solutions. Similarly, how such cascades can impact adaptation measures. Also, how responses can trigger unintended consequences and feedback [maladaptation].

Differentiation of impact pathways: there is a need to identify distinct impact pathways, such as propagation, where systems absorb shocks, versus cascades, where physical tipping triggers self-sustaining socioecological collapse. It is critical to note that the same physical hazard can trigger either pathway depending on the underlying vulnerability. Slow-onset phenomena can result in high impacts and tipping points in socioecological systems.

Summary

There is a need for a framework to translate global/regional tipping elements/systems into regional risk chains, moving beyond linear impact assessments to capture systemic failures in socioecological systems. Such an approach should prioritise identifying the underlying vulnerability conditions, such as governance and economic stability, that determine whether a physical hazard is absorbed (propagation) or triggers a self-sustaining collapse (cascade). Crucially, such a framework should also integrate the irreversible loss of intangible cultural assets and evaluate how biophysical cascades act as feedback loops that fundamentally constrain future mitigation and adaptation capacities.

2.4 Lines of evidence and methodologies for HIETP

2.4.1 Multiple lines of evidence

Multiple lines of independent evidence are needed to properly identify, characterise or anticipate HIETP at global and regional scale and across time scales. New research directions emphasize the need to bring together the climate impact drivers and the regional impacts to derive targeted indicators and analyse cascades of events or compound events having high impact at the regional scales. There are also requirements to provide regional monitoring. Focuses on regional tipping elements with global consequences are now part of the research agenda and better identification and understanding of the regional consequences of tipping points. Discussions highlighted that progress in these directions needs to be able to:

- Link phenomenon to impacts, and this considering either observations, modelling, methods or their combinations.
- Propose new approaches to target observations but including both the HIP events and the impacts together, or including global and regional approaches together.

2.4.2 Observations

Increasingly, more observational (satellite and *in situ*) as well as reanalysis products at global and regional scales are becoming available and can be utilized to extract information relevant to HIETPs. At the same time novel statistical approaches and promising analysis methods have been utilized to obtain information about the non-linear behaviour of the systems and extract early warning signals for the approach to tipping points. Observations of key aspects of the physical and socio-ecological systems that are relevant to tipping elements are needed to be able to extract information about long term trends and distinguish them from variability. Paleoclimate records and reconstructions are being analysed and re-analysed to offer a better view of Earth system behaviour in past climates where there is evidence for tipping dynamics.
Nevertheless, modern observational records are still too short and often lack the spatial and temporal resolution required to capture extreme events and changes in the system that could

trigger cascading impacts. Observations of key aspects of the physical and socio-ecological systems that are relevant to tipping elements are needed to be able to extract information about long term trends and distinguish them from variability. We are often unable to distinguish between long-term trends and low frequency variability which masks the approach to a possible tipping point. For example, the Atlantic meridional overturning circulation (AMOC) observational arrays date back to the 2000s and satellite measurements of sea level, sea ice and ice sheets only date back to the 1990s while column-integrated CO_2, which helps estimate the impact of fires in the Earth system, dates back to 2010s. Moreover, some potential tipping elements, such as Southern Ocean overturning circulation, remain poorly observed. Other systems require enhanced monitoring to detect rapid changes with cascading consequences, including fires (especially underground changes), permafrost, sea ice, subsurface ocean properties, and terrestrial water storage, including their causes and consequences. Therefore, the uncertainty on the estimated trends is still too large.

There are substantial regional biases in the modern record, especially in more densely populated regions, the Global South, remote regions, and extreme environments (including the deep ocean, cryosphere, and others). While this is especially true for pre-modern times, it can be even more pronounced in the satellite record, where "subsurface" observations remain elusive.
While observational data at relevant spatio-temporal scales are lacking across all spheres, paleo data can fill some gaps. However there is bias towards long time scales, as well as regional climate reconstructions. Regarding paleoclimate data, given that no single past epoch exactly mirrors the present or future due to the unprecedented speed of current, anthropogenically-driven forcing, the concept and existence of a "true analogue" is contested. However, specific past epochs might offer valuable insights into singular processes, such as the climate system's response to specific levels of radiative forcing, temperature regimes, sea-ice minima, different ice sheet configurations or extents, or major changes in ocean circulation. This will help validate the physical processes simulated in modern climate models.

The quantity and quality of observations also vary across different spheres, within natural sciences, but importantly when transgressing into societal themes (health, economy, etc.). "Essential Climate Variables" (ECVs) provide a framework to identify and characterize HIETP, but do not convey all the details needed to characterize them at the regional scale. There is no consensus on ECVs across the observational community, modelling and assessment communities.

2.4.3 Modelling

Science related to tipping points relies on a broad hierarchy of modelling tools that span a wide range of complexity. At one end are comprehensive Earth System Models (ESMs) that integrate the physical climate system with biogeochemical, cryosphere, and terrestrial processes, as well as coupled atmosphere-ocean models. Intermediate-complexity ESMs and single-component models—such as stand-alone ocean, ice sheet, or land-surface/vegetation models—provide complementary capabilities, while conceptual models offer highly simplified frameworks for exploring fundamental system dynamics. This hierarchy allows researchers to balance the competing demands of component integration, process detail, and computational cost.

A central challenge is navigating the trade-off between model complexity, the fidelity of process representation, and achievable spatial and temporal resolution. As a result, certain tipping elements or interactions between tipping elements remain insufficiently resolved. For example, ice sheets and their interaction with ocean circulation are not represented in current ESMs. Key permafrost processes, including abrupt thaw mechanisms, are also missing or poorly parameterized. This is also true for fire and dynamic vegetation. Sea-ice and snow processes remain simplified in many models, limiting confidence in high-latitude feedback. When it turns to the water cycle processes are still poorly represented at the regional scales and water use is not included (examples: dams, irrigation, domestic use, ...). Furthermore, fine-scale ocean processes critical to the behaviour of the AMOC are inadequately captured due to resolution constraints. Another persistent difficulty is the limited availability of observational data to constrain and validate models for both present-day conditions and past changes. Most modelling evaluation studies do not account for the dependence of the climate response to tipping phenomena on the mean background state.

A promising way forward is to exploit the full hierarchy of modelling systems, selecting the level of complexity according to the specific research question. Conceptual models and single-domain models are particularly valuable for phase-space exploration and for identifying the conditions under which tipping behaviour emerges. Models of intermediate and full complexity can then be used to test whether the inferred tipping behaviour persists when more realism, or additional stabilizing or destabilizing feedbacks are incorporated, and when interactions among multiple tipping elements are represented (cf. work underway in TipMIP).

2.4.4 Assessment of methods

The largest uncertainties in detecting tipping points stem from incompleteness or inadequacy of the observational record, as well as the fact that paleoclimate and some modern observations derive from periods with a different background mean state and/or trend. Novel methods to synthesize and utilize paleoclimate evidence are critical, for example, fit-for-purpose database compilations, perhaps including machine learning (ML), to extend records into the past.

An important use of observational evidence is to produce indicators of the approach to tipping (early warning signals). These are statistical or mathematical tools for detecting tipping; however, their applicability needs to be tested as more observational data become available, as success may depend on a particular observational window and results may depend on the variables that are being monitored.

To address tipping points hierarchies of models are necessary, including idealized reductionist models, coupled models, and Earth system models (ESMs). However, we need to distinguish between idealized frameworks and the “real world” in Earth system modelling in the context of applicability. For example, irreversibility and hysteresis are typically defined in the context of dynamical systems where any perturbation (forcing) is added on a climate background in equilibrium. The role of multiscale climate variability and interactions with the background climate state is still difficult to characterise and requires being able to combine different approaches (system dynamics, statistics, process studies). However, anthropogenic climate change is a series of perturbations (forcings such as freshwater, compound extremes) added to the background of a changing climate (due to greenhouse gas emissions as well as other anthropogenic stressors).

Methodological approaches in analysing model output are also providing information for noise-induced tipping, where ensemble mean-based approaches are not useful, and the focus is placed on event-based analysis. Physics-informed machine learning and other statistical methods are becoming more useful as they provide links to the physical system and have better interpretability and explainability.

With regards to the detection of HIETP “traits” or characteristics, it is difficult to assess “true irreversibility” in the context of a climate that never returns to the “original” or unperturbed state. A unified framework for the characterization of “traits” of tipping points and the hazards that they produce is lacking and the characterization of the physical drivers and biogeochemical impacts is difficult. Resilience of a particular tipping element is an important feature in the evolution of a tipping process, yet there is large uncertainty in its quantification. For example, the evolution of carbon sources and sinks after a tipping point has occurred and how they interact with the climate system, reinforcing or weakening the tipping point (reversibility).

Storyline descriptions of the approach to a tipping point and the subsequent cascade of impacts across different physical, and socio-ecological systems is proven helpful in situations of deep uncertainty, unknown likelihoods of occurrence and large-scale impacts.

2.5 Recommendations for WGI

1. Consider the updated definitions/concepts recommendations from the workshop and ensure consistent use of language across working groups (particularly Chapter 1s of WGI, WGII and WGIII, and WGI Chapter 8).
2. Distinguish between local/regional and large-scale/global high impact events (extremes, compound extremes, tipping systems, etc) to help define the boundaries between Chapters 3, 7, and 8 and to improve clarity in communication. We identified five types of high impact events:

   Type 1: *Local/regional* high impact events (WGI) with *local/regional* physical and biogeochemical consequences (WGI) and with *local/regional* impacts (WGII/III).

Example: Local marine heatwave leads to regime shift in local ecosystem structure with regional impacts on fisheries.

- Potentially being in Chapter 3 and 7

Type 2: *Local/regional* high impact events (WGI) with *local/regional* physical and biogeochemical consequences (WGI) and with *large-scale/global* impacts (WGII/III).
Example: Spatially compounded heat-drought events over food basket regions leading to a global food shortage.

- Potentially being in Chapter 3 and 7

Type 3: *Local/regional* high impact events (WGI) with *large-scale/global* physical and biogeochemical consequences (WGI) and with *large-scale/global* impacts (WGII/III).
Example: Amazon dieback leads to additional global warming.

- Potentially being in Chapter 8

Type 4: *Large-scale/global* high impact events (WGI) with *large-scale/global* physical and biogeochemical consequences (WGI) and with *large-scale/global* impacts (WGII/III).
Example: Strong AMOC weakening/collapse leading to lower temperatures in the Northern Hemisphere and global redistribution of precipitation and sea level rise.

- Potentially being in Chapter 8

Type 5: *Large-scale/global or regional* high impact events (WGI) with a range of *regional-scale* physical and biogeochemical consequences (WGI) and with *regional* impacts (WGII/WGIII) in different locations.
Examples: i) Collapse of the Greenland ice sheet or the West Antarctic Ice Sheet leading to a strong sea level increase and potentially threatening the livelihood of small-island states; ii) AMOC collapse and effects on the West African monsoon.

- Potentially being both in Chapters 8 and 7

3. Consider high impact events that are not necessarily associated with physical tipping (e.g. the Northeast Pacific 2013-2015 Marine Heatwave 'The Blob').
4. Enhance collaborations across IPCC Working Group research communities: Coordination between WGI chapters 7 and 8, as well as regional chapters of WGII (7-13, possibly also chapter 2 of WGII).
5. Identify the regional/global consequences when tipping thresholds are crossed (i.e. what-if scenarios), and include this information in the interactive WGI/II IPCC Atlas.
6. Contrast worlds with and without tipping-point crossings. For example, what the world would look like if the Amazon Rainforest dies out, or if the AMOC collapses, or if multiple tipping points are crossed.
7. Consider cascading consequences as well as interactions between tipping systems (e.g. Greenland melt tipping AMOC tipping monsoon systems).

8. Assess the effect of HIETPs on critical climatic-impact drivers (CIDs, e.g. extreme indices) and on climate adaptation/mitigation relevant metrics, such as the Transient Climate Response to cumulative CO_2 Emissions (TCRE), Zero Emissions Commitment (ZEC), and remaining emissions budget (REB). Consider collaborating with WGII and WGIII to determine which CIDs are most useful/relevant. Chapters 5, 6, and 8 in collaboration with Chapter 9.
9. Consider developing HIETP storylines across WGs, employing a storyline approach to formulate physical scenarios for tipping elements and high-impact events, particularly in situations involving deep uncertainty.
10. Consider developing burning embers diagrams (for WGI and WGII) that depict scenarios both with and without tipping-point thresholds being crossed. Also consider developing separate burning embers for different tipping systems (in line with some recent literature).
11. Assess model limitations in representing processes critical for tipping elements (e.g. drought-ecosystem-carbon feedbacks, ice shelf-ocean interactions).
12. Assess a hierarchy of modelling systems for climate and impacts of tipping points, including TIPMIP-ISIMIP and TIPMIP-RCM simulations if available.
13. Assess tipping behaviour in a hierarchy of models – idealized, coupled, forced, decadal prediction models, ESMs, global coupled climate models without an interactive carbon cycle. Develop appropriate methodology to assess a diverse pool of simulations (e.g., do the coupled and uncoupled models weigh the same?) based on complexity, skill in reproducing observations, paleoclimatic abrupt or tipping dynamics, etc.
14. In addition to the ensemble mean response also assess the stochastic response to forcing across model ensemble members to obtain information for the likelihood of noise-induced tipping behaviour. Additionally, use event-based approaches from large ensemble simulations whenever possible.
15. Develop an appropriate framework for estimating uncertainties: in terms of observations, paleoclimate proxies, models, etc.
16. Assess different future emissions pathways, including scenarios with temporary overshoot, for TP crossing and evaluate how the consequences of tipping points crossing under those different scenarios compare with those driven by global warming alone (note this is preferable to using experiments focusing on tipping under preindustrial conditions). (WGI chapters 8, 6, 9).
17. Assess the potential for monitoring resilience of tipping systems and detecting early-warning indicators using observations or proxy data in key regions (e.g., the Amazon and Congo rainforests, the Southern Ocean, the North Atlantic), as well as through emerging statistical techniques and decadal prediction systems. Evaluate the suitability of existing observational and model outputs as well as proxy data and statistical techniques.
18. Assess connection points to impact assessments (WGII) with and without CIDs, Coordination between WGI chapters 8 and 7, as well as regional chapters of WGII (7-13), possibly also WGII chapter 2.
19. Assess interface to mitigation assessment (WGIII, e.g., nature-based CDR) - Coordination between WGI chapter 8 and WGIII chapter 15.
20. Solar Radiation Modification (SRM) is an open question to possibly be assessed (coordination between WGI chapters 8 and 9).

21. Consider additional stressors and forcings in addition to greenhouse gas forcing (e.g., land use change, pollution).
22. Assess effects of extreme/compound events on tipping systems and dynamics (joint assessment between chapters 8 and 7 in WGI).
23. Assess interlinkages between tipping systems and between cascades of Earth system processes.

Writing

24. One potential structuring could be compiling information based on confidence (works very well for SPM and factsheets, but it may not work for individual chapters), mentioning spatial and temporal scales helps, and focusing on specific regional impacts.
25. Suggest clarifying spatial scales, whether for a) the HIETP themselves and b) the impacts of HIETPs (see five types outlined above).

2.6 Recommendations for WGII

26. To **assess impacts and risks** of tipping dynamics and high impact futures, WGI can provide information on drivers, their timing, spatial extent, and amplitude that are relevant to WGII impacts assessment (e.g., the IPCC atlas, storylines, burning embers), recognising they will be superimposed with background impacts of climate change.
27. **Illustrative storylines** of HIETP for **cascading and compounding impacts** from HIETP and human pressures, and adaptation options, possibly together with WGI. For example, with simple cascade examples and storylines (e.g. tipping element => CID change => sectoral impact => cross-sector cascade => adaptation options).
28. **Consider the certainties and uncertainties** of HIETP, including their past and projected occurrences and impacts, and agree on a framework to assess and communicate the cascading uncertainties.
29. **Assess adaptation solution space** to address HIETP, including the available options and their limits, co-benefits, adaptive pathways, signals of change informing adaptation, and integrate **traditional and Indigenous knowledge** in impacts and adaptation pathways.
30. Evaluate the soft and hard **limits to adaptation** in the context of HIETP, differentiating between systems where adaptation is effective and feasible versus those where it is not or difficult. This can inform WGIII on mitigation scenarios and options.
31. **Regionalisation via risk matrix**: The assessment of regional tipping cascades (such as AMOC-induced monsoon shifts affecting the Sahel or sea-level rise destabilising major deltas) utilising a Thematic X Regional matrix to systematically identify where critical conditions transition representative key risks into high or very high-risk status.
32. **Recalibration of burning embers** diagrams (Reasons for Concern)*:* Inclusion of burning embers diagrams that attempt to contrast risks with and without tipping events and high impact events. The AR7 burning embers could also illustrate how adaptation effectiveness may change with inclusion of HIETP, thereby increasing residual risk.

33. **Causal network methodologies**: Adopt causal network methodologies to visualise and assess propagation pathways (tipping element => CID => sectoral impact => cross-sector cascade). This must ensure that slow-onset events (e.g., ocean acidification) are rigorously linked to sudden socioecological tipping points.
34. **Intangibles and maladaptation**: Evaluate the limits of adaptation for intangible assets, acknowledging that cultural relations and moral frameworks may face existential threats where physical adaptation is impossible. Simultaneously, assess how reactive adaptation to HIETP can paradoxically exacerbate impacts (maladaptation) and contribute to cascading risks.

Summary

We recommend that WGII operationalises the assessment of tipping risks by collaborating with WGI to integrate specific physical driver data (including timing, spatial extent, and rate, e.g. based on the WGI Atlas) into a Thematic X Regional matrix to identify critical conditions, where risks transition to high status with and without adaptation. This approach necessitates the recalibration of "burning embers" diagrams to illustrate how tipping dynamics may increase risk, introduce new limits or convert soft adaptation limits into hard limits, thereby increasing residual risk. With storylines, WGII can illustrate how risks can unfold and describe alternative adaptation pathways, acknowledging the (un)certainties of tipping dynamics. Furthermore, the assessment should utilise causal network methodologies to map propagation pathways from physical elements to socioecological cascades, while rigorously evaluating the adaptation solution space, incorporating traditional and Indigenous knowledge, and assessing the existential limits for intangible cultural assets.

2.7 Recommendations for WGIII

35. Emissions pathways, remaining carbon budgets and feedbacks: Assess how HIETP (such as permafrost thaw and Amazon dieback) may contribute to feedback on emissions, necessitating a revision of remaining carbon budgets to explicitly account for currently unaccounted emissions from high impact events such as wildfires as well as associated uncertainties.
36. Resilience of mitigation strategies: Evaluate the effectiveness, mitigation potential, and technical feasibility of specific strategies (such as for hydropower, bioenergy, ocean-based energy, and Nature-based Solutions) when exposed to HIETP conditions. This must include assessing the adaptability of these systems, such as the viability of large-scale biomass sequestration when exposed to high-impact wildfire regimes.
37. Feasibility and limits of CDR: Assess the feasibility, effectiveness, and scalability of CDR under HIETP scenarios (e.g. associated with impacts on the biosphere), with expanded research into the stability of terrestrial and marine carbon sinks under high-warming trajectories to determine the physical limits of these strategies.
38. Compounding capacity constraints: Analyse how HIETP compounds with non-climatic stressors (e.g., economic disruption, conflict) to constrain the societal and institutional capacity required to implement mitigation measures.

39. Risks of climate interventions: Develop rigorous frameworks to assess the risks, implications, and impacts of climate interventions (such as Solar Radiation Modification - SRM) as responses to the threat of HIETP. This includes evaluating temporal mismatches, irreversibility risks, and the broader implications for social systems, ecosystems, and existing mitigation strategies.
40. Mitigation as risk reduction: Assess how avoiding every fraction of a degree of further warming through fast and ambitious mitigation reduces the probability of triggering HIETPs, linking mitigation ambition directly to avoided tipping risks.
41. Sustainable development (SD) synergies: Evaluate the role of SD as an integrating framework to synergise adaptation and mitigation responses to HIETP, specifically identifying pathways that simultaneously reduce vulnerability to cascading impacts and advance decarbonisation to minimise resource competition and maladaptation.

Summary

We recommend that WGIII assess how HIETP could necessitate the revision of carbon budgets to account for feedbacks on emissions, while evaluating the physical viability and limits of mitigation and CDR strategies under these extreme conditions. The assessment must analyse how compounding non-climatic stressors constrain societal capacity, whilst positioning SD as a framework to synergise adaptation and mitigation. Finally, it is important to quantify mitigation as a primary risk reduction mechanism of HIETPs, and rigorously evaluating the irreversibility risks associated with climate interventions (e.g., SRM).

2.8 Recommendations across WGs

42. **Definitions:** Use definitions and concepts that apply for all WGs as much as possible, cross-reference them in the IPCC Glossary.
43. **Cross-WG unified framework**: Establish a unified cross-WG framework, that links WGI physical phenomena (including gradual changes triggering non-linearities) directly to WGII socioecological cascading risks and WGIII mitigation constraints. This framework must explicitly model feedback loops where WGII impacts (e.g., forest dieback or sink loss) become new WGI drivers that modify radiative forcing and reduce mitigation capacity.
44. **Characterisation of traits:** Develop and apply a clear framework for the characterization of traits/features of tipping elements/systems and the hazards they produce that will be useful in the analysis of physical drivers, but also biogeochemical systems and human and ecological systems.
45. **Interaction between tipping systems:** Consider potential interactions between tipping systems (i.e. extent to which the reaching of a tipping point in a tipping system may also trigger tipping in other systems, e.g. as a result of additional global warming).
46. **Scenario dependence and carbon constraints**: Integrate HIETP (e.g. permafrost thaw and Amazon dieback) into remaining carbon budget calculations and mitigation pathway assessments, acknowledging that the probability and timing of tipping elements depend strongly on emissions pathways. This includes stress-testing WGIII strategies (such as

hydropower, bioenergy, Nature-based Solutions, CDR) against WGI physical tipping scenarios to determine adaptive capacity limits.

47. **Cross-WG storylines and cascades**: Develop illustrative cross-WG storylines that operationalise the unified framework to assess interactions between tipping systems. These storylines should capture both regional-to-regional cascades (e.g., marine heatwaves affecting local fisheries) and regional-to-global cascades (e.g., spatially compounded extremes in breadbasket regions triggering global food shortages).
48. **Operational assessment tools**: Enhance operational assessment tools by integrating tipping elements/systems risks into the interactive atlas (including post-tipping climate states like AMOC shutdown) and expanding CIDs to include high-impact scenarios. Additionally, incorporate tipping points into WGII "burning embers" diagrams to visualise risk transitions with and without adaptation.
49. **Intervention risks and synergies**: Evaluate the cross-WG implications of climate interventions (such as Solar Radiation Modification), assessing risks to social and ecological systems alongside mitigation interactions. Concurrently, assess the role of SD as a synergising framework to align adaptation and mitigation responses to HIETP.

2.9 Recommendations for physical climate science research

50. Use or improve definitions of concepts related to tipping points/elements/dynamics.
51. Develop physical scenarios for tipping elements and high-impact events for deep uncertainty using storyline approach, such as ‘what does the world look like if the Amazon rainforest dies back?’ ‘What does it look like if the AMOC collapses?’, could be an input to the interactive IPCC Atlas.
52. Determine and analyse regional tipping elements in addition to global tipping elements.
53. Consider additional stressors and forcings in addition to greenhouse gas forcing, such as deforestation or pollution.
54. Recommend to CORDEX to compute regional climate model simulations for tipping dynamics and consider identification of regional tipping elements/systems.
55. Recommend that ISIMIP and CORDEX collaborate with TIPMIP.
56. Also consider high impact events that are not necessarily associated with physical tipping, but can trigger self-amplifying, abrupt or irreversible change in impacts (collaborations across IPCC WG research communities).
57. Physical climate scientists should provide science identifying signals from cascading physical systems to inform the risk of cascading impacts to ecosystems and society (which may/or may not necessarily be associated with physical tipping).
58. Identify connection points to impact research with and without CIDs, also starting from impact systems.
59. Address model limitations in representing processes critical for tipping elements (e.g. drought-ecosystem-carbon feedbacks, ...).
60. Address the interface with mitigation research (e.g., nature-based CDR).

61. Consider the potential effects of SRM on HIETP, which is an open question.
62. Consider the effects of severe compound events on tipping elements and dynamics.
63. Undertake targeted perturbation experiments under warmer conditions (sensitivity experiments).
64. Produce assessments by societal impact rather than temperature scenario.
65. Sustain and expand long-term observational programs.
66. Improve paleo-proxy records towards seasonal resolution and applicability to modern climate change.
67. Effort needs to be placed to compile fit-for-purpose databases of past tipping dynamics and high impact events, perhaps including machine learning to extend records to the past.
68. Further advance research on early warning and monitoring – including indicators of systems' stability – of tipping systems in key regions (Amazon Rainforest, Congo rainforest, Southern Ocean, North Atlantic) and evaluate robustness against noise, data uncertainty and small shifts in location of features rather than collapse.
69. Identify a database of high-value observations and model output that can be used to identify the lead-up to tipping or abrupt change for development of early warning signals.

2.10 Recommendations for impact, risk and adaptation research

70. To **assess impacts and risks** of tipping dynamics and high impact futures, including cascading and compound impacts and risks, such as on food systems, health, built environment, economy, conflict, and human mobility (see also 2.3). WGI can provide information on drivers, their timing, spatial extent and amplitude that are relevant to WGII impacts assessment (e.g. IPCC Atlas) recognizing they will be superimposed with background impacts of climate change.
71. **Consider the certainties and uncertainties** of HIETP, including their past and projected occurrences and impacts, and agree on a framework to assess the cascading uncertainties and communicate them.
72. **Regional downscaling:** Prioritise research that downscales global tipping point frameworks to regional and local contexts, identifying specific "impact tipping points" where local coping capacities are overwhelmed.
73. Consider including experts to capture regional impacts and consequences for adaptation.
74. The adoption of **values-based assessment methodologies** (akin to IPBES) to quantify and communicate the loss of intangibles, culture, and social cohesion which are currently absent from standard economic risk models.

Summary

The scientific community must prioritise the development of integrated assessment frameworks that bridge physical drivers and socioecological impacts. This entails establishing rigorous methodologies to downscale tipping dynamics to regional contexts (potentially utilising a Thematic X Regional matrix approach) to identify specific impacts where local coping capacities are overwhelmed. Furthermore, research must advance causal network modelling to map cascading uncertainties and quantify the transition from soft to hard adaptation limits. Finally, we call for the adoption of values-based assessment methodologies, integrating diverse regional expertise, to capture the irreversible loss of intangible cultural assets and social cohesion often omitted from standard economic models.

2.11 Recommendations for mitigation research

75. Emissions feedbacks and carbon budgets: Quantify the contribution of HIETP (specifically biophysical thresholds such as permafrost thaw and Amazon dieback) to emissions feedbacks, necessitating a revision of remaining carbon budgets to explicitly account for currently unaccounted emissions from high impact events like wildfires.
76. Resilience of mitigation strategies: Evaluate the physical resilience, mitigation potential, and technical feasibility of specific strategies including hydropower, bioenergy, ocean-based energy, and Nature Based Solutions, when exposed to HIETP conditions.
77. Feasibility and limits of CDR: Assess the scalability and physical limits of CDR strategies under HIETP scenarios, including expanded research into the stability of terrestrial and marine carbon sinks under high-warming trajectories.
78. Compounding capacity constraints: Analyse how HIETP compounds with major non-climatic stressors (e.g., economic disruption, conflict) to constrain the societal and institutional capacity required to implement mitigation measures.
79. Mitigation as risk reduction: Quantify the specific risk reduction potential of fast and ambitious mitigation, determining how avoiding every fraction of a degree of further warming reduces the probability of triggering HIETPs.
80. Intervention risks and irreversibility: Develop rigorous frameworks to assess the temporal mismatches and irreversibility risks associated with climate interventions such as SRM, including interactions between SRM, mitigation, and adaptation.
81. Sustainable development synergies: Explore how HIETP constrains SD pathways, and conversely, how SD frameworks can enhance the capacity of human and natural systems to reduce risk and support mitigation.
82. Societal perception and policy demand: Investigate how the lived experience of HIETPs, localised impacts, and cascading failures influence public perception and policymaker demand for knowledge, and how this shapes the political feasibility of mitigation action.
83. Scenario development: Develop scenario storylines and modelling studies that explicitly account for HIETP to improve their utility for mitigation policy planning.
84. Cross-working group priorities: Prioritise research into boreal wildland fire and abrupt Yedoma permafrost thaw as critical HIETPs with cross-continental implications for resilience, whilst identifying near-term interventions (e.g., forest management) to preserve carbon sinks.

Summary

We call for a coordinated research agenda to quantify how HIETP (such as boreal wildland fire and abrupt Yedoma permafrost thaw) could modify remaining carbon budgets, necessitating a re-evaluation of mitigation pathways to account for these non-linear emissions. Concurrently, research must assess the physical resilience and scalability of mitigation strategies (e.g., bioenergy, hydropower, CDR) when exposed to cascading tipping risks and investigate how policymaker engagement and societal experiences of impacts influence mitigation capacity. Finally, we recommend developing rigorous frameworks to assess the irreversibility risks associated with climate interventions like SRM.

2.12 Communication workshop outputs

Outputs from communications workshops focusing on communicating HIETPs to non-specialist audiences, with summary prepared by the facilitator, Sue Escott.

Powerful communication – common themes

- Make HIETPs more relatable by starting with what we are already experiencing or know about and building the narrative from there.
- HIEs are more relatable than TPs, so it might be easier to engage people by focusing on these first.
- Engage people by avoiding narratives around abstract, catastrophic, doomsday scenarios and focus instead on specific issues that may seem more tangible and manageable.
- Work hard to correct misconceptions around thresholds and timescales.
- Use analogies and comparisons (e.g., earthquakes) to help audiences understand that uncertainty is a part of many people's lives.
- Try to answer the question, 'So what?' So, move quickly from HIETPs to the potential consequences. Ultimately, to policymakers and others, it's the impacts that matter.
- Paint 'word pictures' to help people visualise events. Give concrete examples.
- Show empathy – go beyond delivering the scientific facts because people engage better when the facts relate to their life and their values. It's about connecting the dots between the changing climate and people's lives.

Focusing on communication around individual HIEs

- A three-part narrative focusing on (1) what we know; (2) what is less certain; (3) what we are doing about it, may be an effective way of explaining a specific event to non-specialist audiences.
- Always start with context – setting out the magnitude of the issue in tangible terms (e.g., comparing the amount of carbon stored in permafrost with what is currently in the atmosphere). This will resonate with people.
- When talking about what we know, explain how we know it in simple terms (e.g., it's happened before).
- When outlining the uncertainties, there is value in explaining the complexity of these systems, the variables, and the efforts being made to get answers.

The big unanswered questions

- How to respond to, 'When might these HIETPs happen?'/'How likely are they to happen?'

The solutions space – giving people hope and agency

- Positivity is important – we have solutions, there are benefits to acting now.
- Counter an inclination to delay action by talking about low-risk or no-risk options and no-regret actions.
- Focus on co-benefits. There are things we can do now that will improve our lives and prepare us for future impacts.
- There are merits in offering both top-down and bottom-up approaches to solutions, highlighting the value of individual/community action and the ripple effect as experiences are shared.
- Encouraging individual responsibility is valuable but it should not lead to feelings of guilt. That said, there was a focus on targeting those who are wealthier because they are best placed to do (a lot) more.
- Recognising that individual circumstances are different is important and realising that people are more likely to act if they feel that it's the right thing to do.
- Understanding motivators (e.g. security, health, financial benefits) and communicating through empathy (listening and validating/acknowledging concerns) are effective approaches.
- Find the balance between communicating the urgency of some of these issues and generating panic, which can lead to inaction.
- And it's worth repeating the message: keeping global warming as close as possible to 1.5°C limits the risks of reaching global tipping points.

What makes a credible, powerful spokesperson – some discussion points

- Authenticity is key. People recognise and trust spokespeople who seem genuine – open/transparent.
- The best spokesperson for a particular audience may not be the most knowledgeable – e.g. a younger audience might find a younger scientist more engaging even if they are not as experienced.
- Having your own agenda and getting it across in your interviews should be the goal. A good interview is not just about giving a comprehensive answer to each question – it's about acknowledging, addressing or answering each question but then working hard to inform and educate.
- Recognising that if you can't answer a question directly, you can still inform people (e.g. if there hasn't been an attribution study done for a particular event, it is still possible to talk about the increasing likelihood/intensity due to climate change etc.).

- It can be valuable to express emotions – it's ok to be concerned about potential HIETPs.
- Spend time briefing (educating) specialist journalists. Give them the background to be able to put each story in the broader context.
- And a message for IPCC: messages that are designed to work for everyone might not work for anyone and a more tailored approach focusing on different audiences might be needed in AR7.

3. Workshop proceedings: Summary of daily program and discussions

3.1 Day 1 – The science of HIETP

Brief overview of the day

The first day was dedicated to exploring the science of HIETP from various angles. Following the opening remarks by the meeting Co-Chairs and by representatives of the funders that supported the meeting, three keynotes provided an historic overview on HIETP in global scientific assessments, from a WGI, WGII and IPBES perspective respectively. In two separate panels after lunch, lead authors of the WCRP tipping points assessment (TPA) introduced latest developments and challenges related to framing and concepts and elaborated on key findings of their work for systems and knowledge sources for the ocean, cryosphere, boreal forest and permafrost, tropical ecosystems, and advances and gaps in modelling. Participants then formed small groups to exchange views and gather additional knowledge in a world café format. Each table was dedicated to a topic or Earth system component. The group identified key issues that emerged during discussions for report back, and a full transcript was made available online to inform the discussions on the following days. The final session of the day gave space to perspectives in HIETP from usually less represented geographies: IPCC Bureau members provided insights from their respective regions, followed by a plenary discussion on different perceptions and priorities across the world. After closing remarks by the SSC Chairs, the SSC met to evaluate the day and align the program for day 2. Most participants then embarked on a dinner cruise on the Seine, by kind invitation by the IPSL international unit, carrying forward the high spirits encountered throughout the day.

3.1.1 Summary of opening remarks

Moderator Pascale Braconnot, WCRP JSC, opened the first session, welcoming participants and government representatives to the Jussieu Campus and the workshop.

Sophie Godin-Beekmann, Director of L'Institut Pierre-Simon Laplace – IPSL addressed the room also in the name of Sorbonne University and Centre national de la recherche scientifique- L'Institut national des sciences de l'Univers (CNRS-INSU). She gave a broad overview of climate research in France and the various institutes, especially IPSL, where several researchers are involved in EU projects on tipping points. She highlighted the importance to adopt a multi-disciplinary approach to this topic, and the timeliness of the workshop.

Corinne Borel, Ministry of Higher Education and Research, France, emphasized that in addition to multi-disciplinarity, a new appreciation to risk management and multi-ministerial cooperation was required. Pointing to the current geopolitical context she underlined that science must serve as a foundation for society and that solutions from research are critically important. Underscoring the fact that the workshop was happening during the anniversary of the Paris Agreement, she said its outcomes will also inform future research directions, beyond the first IPCC lead author meeting in the following week.

Marie-Hélène Schwoob, Ministry of Ecological Transition, spoke about the high level of climate change-related financial losses already happening worldwide, and pointed out how consequences of tipping points could seriously impact Europe and France. She stressed that disaster risk reduction is critical to her ministry and elaborated on the recently published 3rd national adaptation plan for France, including on knowledge improvement as a critical part of national adaptation planning. She urged that projections and scientific knowledge of high impact events are refined and improved and highlighted that her ministry requires the latest available science on this field to engage in international political negotiations on climate change.

Addressing participants by video message, James Palmer, Ministry for the Environment of New Zealand, stated that HIETPs were no longer distant possibilities but looming realities, and stressed the existential dimension of tipping points. He lamented insufficient ambition despite increasingly severe impacts and questioned whether policy makers and the public really understand the extent to which civilisation depends on the regulating relationships within the Earth system. He thanked everyone present for dedicating their time and expertise to develop actionable science that can be integrated into decision making tools, models and scenarios to address this shared challenge.

Tim Naish, WCRP Joint Scientific Committee Chair and Co-Chair of the SSC, outlined the structure and vision of the World Climate Research program, and explained how WCRP helps coordinate the international research community to deliver climate science and products for IPCC Assessment Reports (e.g. through CMIP). He pointed to two high-level assessments that WCRP started in support of AR7: The Transient Climate Response to cumulative carbon Emissions (TCRE) assessment, and the High-impact climate events, tipping points, and irreversible regional impacts assessment. He briefly explained how the collaboration between IPCC working group I and WCRP led to this workshop aligned with LAM1 to allow IPCC authors and the wider community of experts to come together. He acknowledged the funding provided by WCRP, the Government of New Zealand, the Government of France and additional resources from the local host institutions.

Robert Vautard, IPCC WGI Co-Chair and Co-Chair of the SSC elaborated on key issues that called for holding this workshop. He recalled that several countries proposed an IPCC Special Report on tipping points for the seventh assessment cycle, and highlighted challenges around tipping points pertaining to misleading terminology, confusing concepts and difficult communication. He presented the dedicated chapter agreed in the WGI outline which responds to the need to broaden the topic to high impact event types of interest that may not qualify as « tipping ». He reiterated the goals of the workshop, including to provide recommendations to each WG on definitions and chapter/WG boundaries of the assessment so that high impact events, tipping points and their consequences are treated holistically and consistently by all WGs in the IPCC 7th Assessment Report.

Figure 1: Group photo of workshop participants (© Daniel Peyronel, ICOM-IPSL).

3.1.2 Summary of keynote session

10.30 - 12.00	**Overview and critical appraisal of High Impact Events and Tipping Points (HIETP) in global scientific assessments** Moderator: Tim Naish, WCRP Chair **Kick-off survey on concepts and perceptions** (Robert Vautard, IPCC WGI Co-Chair) **Keynotes and exchange** ● IPCC WGI (Thomas Stocker, AR5 WGI Co-Chair) ● IPCC WGII (Zelina Zaiton Ibrahim, AR6/AR7 WGII CLA) ● IPBES (David Obura, IPBES Chair)

Robert Vautard started the session with a mentimeter poll that required participants to categorize a series of different climate related events according to IPCC definitions as **tipping point, abrupt change, low-likelihood high impact outcome (LLHI), cascading impact** and **climate extreme**. This interactive exercise served to entice participants to reflect on the ambiguities and challenges with existing definitions, and to show the range of views in the room.

Following this exercise, moderator Tim Naish invited the first speaker, former WGI Co-Chair Thomas Stocker, University of Bern, to share a historical perspective on HIETP.

In his talk, Professor Stocker retraced the history of science on AMOC events, starting from sudden state change first raised in a conceptual model of the deep ocean in 1961, and elaborated on the development of model capacity to represent tipping behaviour in the ocean, and on the role of observations and paleo-evidence to constrain our understanding. He highlighted the range of terms used since the 1st IPCC AR (1990), such as multiple equilibria, abrupt change, irreversibility, surprise, tipping point and HILL. He recalled that IPCC WGI AR4 had a box about abrupt changes, identifying six potentially affected systems (AMOC, arctic sea ice, glaciers and ice caps, the Greenland and West Antarctic ice sheets, vegetation cover, atmosphere and ocean-atmosphere regime). AR5 expanded this analysis, and AR6 provided a very comprehensive assessment, albeit distributed across the report, feeding into a more detailed representation of the 5th ember (large-scale singularities) of the "Reasons for Concern" in WGII. He applauded the decision to include a one-stop chapter for these events in the WGI section of AR7, stressing the importance of headline statements in the Summary for Policymakers (SPM), feeding relevant information into other WGs, and ultimately the link to the Synthesis Report in the context of WGI's policy-relevance. Finally, he proposed to include climate model simulations that exhibit tipping transitions (e.g., results from TIPMIP and WhatifMIP and other relevant sources) in the interactive, cross-WG Atlas specifically as a tool for more comprehensive risk analyses.

Discussion during Q&A touched upon the transfer of information to WGII, including through the interactive Atlas, potential confusion created by the term "low-likelihood" high impact event, and whether to keep using the term "multiple equilibria".

The next keynote by IPCC WGII AR6/AR7 CLA Zelina Zaiton Ibrahim gave a reflection from WGII on HIETP, cascades and climate risk. Starting with a brief history of the topic in WGII, she elaborated on the usage of terms such as risk, extreme, collapse, catastrophic from the AR1 to AR6, noting a dramatic increase, since AR5 also for the terms tipping, low probability and high impact. She traced the history of the "burning embers" chart from the Third Assessment Report (TAR) to AR6, noting its evolution to indicating levels of confidence, regional and more detailed system specific embers (e.g. for the ocean), differentiation of risk based on socioeconomic pathways and adaptation levels, and vast methodological improvements. She briefly touched upon the issue of social tipping points, which can occur before and independently of Earth system TP, with more research needed for their quantification.

During Q&A, discussion centred on the value of the embers as a visualisation tool for communication, questioned their influence on policy, and emphasized their potential to link across WGs.

David Obura, Chair of The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), introduced the mission and organisational structure of IPBES, the links to IPCC, past collaborations and the joint aspiration for increased cooperation in the future. He highlighted IPBES's engagement with Indigenous Peoples and pointed towards the ongoing 2nd Global Assessment (due likely in late 2028) that will feature a dedicated chapter on Indigenous Knowledge. He discussed the example of mass bleaching of tropical coral reefs as a case where ecosystem tipping is now expected at lower temperatures, and the existential crises affecting coastal and marine ecosystems through multiple drivers additional to climate change. In looking at the solution-space, including climate-related response options, the IPBES nexus report identified many options with the potential to deliver benefits across sectors and systems, underlining the importance of a holistic view.

The very lively Q&A session reflected the climate community's deep interest in collaborating and learning from IPBES's experiences. Points raised included the role of evolutionary adaptation in coral reefs, improving the representation of biosphere tipping points by modelling biosphere complexity as fully as possible while being mindful of limitations, and strengthening the biodiversity-climate nexus by developing more joint literature. In the context of nature-based solutions, the importance of using a fully integrated systems framework instead of maximising a single component without considering connected effects. The fact that overshoot pathways will have irreversible impacts on ecosystems, limiting future options was highlighted.

To conclude the session, another mentimeter exercise polled participants on their priorities regarding HIETP research and the relevance of social dimensions (Figure 2).

Figure 2: Results of a mentimeter poll on research priorities in the context of HIETP.

3.1.3 Summary of WCRP concepts overview

13.00 - 14.00	**WCRP Tipping Point Assessment - Overview panel on framing, concepts, and challenges** Session Facilitator: Gabriele Hegerl, WCRP TPA lead, inputs by TPA lead authors Rationale and Key Questions (Gabriele Hegerl) Learnings on definitions, scope and framing (Hannah Liddy) Challenges with conceptualizing “high impact/threshold events” from the impacts side (Alaa Al Khourdajie) Q&A and discussion

Gabriele Hegerl, lead of the WCRP assessment paper on "High-impact climate events, tipping points, and irreversible regional impacts assessment" (TPA) introduced the session, which provided an overview of, and rationale for, the WCRP TPA. In particular, she and the presenter team (Hannah Liddy, Alaa Al Khourdajie) outlined some questions for the workshop based on key learnings from writing the ZOD draft of the WCRP Assessment. These included 1) definitions, scope and framing, 2) challenges with conceptualising high impact/threshold events, recognising that multiple definitions are used from physical systems to socioeconomic impacts, and 3) how do we better communicate them. She explained the aim of the assessment was to inform the IPCC AR7 WGI Chapter 8, "Abrupt changes, low-likelihood high impact events and critical thresholds, including tipping points, in the Earth system", and work towards building scientific consensus, posing the question to the audience whether an AR7 cross-working group framing could be developed during this co-sponsored workshop?

Gabi then gave an overview of the assessment outline and noted that it includes eight chapters written by over 75 authors. The chapters are on definitions & concepts, oceans, cryosphere, boreal, tropical, modelling, impacts, conclusions and ways forward. It is likely to be completed towards the middle of 2026. The assessment is framed to address the highest-impact outcomes we are concerned about.

Hannah gave an overview of the first chapter of the assessment, which looks at the framing, scope, and definitions of high impact events and tipping points. The section focuses on the most physically consequential potential outcomes, not an exhaustive inventory of all climate tipping points. It synthesizes evidence from paleoclimate, observations, process understanding, and multi-model analysis and aims to define the state of scientific understanding, quantify uncertainty, and assess likelihood across warming levels and trajectories. The authors are now considering integrated, or separate, expert elicitation to avoid overconfidence and capture uncertainty in thresholds and risks. Looking at different concepts, the aim is to define tipping systems using a trait-based approach (e.g., Kopp et al., 2025[5], see also Winkelmann et al. 2025[6]) that maps coherently onto underlying mathematical mechanisms while remaining relevant to risk analysis.

It is also important to note that the authors do not enforce a strict or exhaustive definition of a tipping point but rather use a practical definition, where 'tipping system' is defined as a large-scale

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[5] Kopp, R.E., Gilmore, E.A., Shwom, R.L., Adams, H., Adler, C., Oppenheimer, M., Patwardhan, A., Russill, C., Schmidt, D.N., York, R. (2025) "'Tipping points' confuse and can distract from urgent climate action", *Nature Climate Change* **15**, 29-36.

[6] Winkelmann, R., Dennis, D.P., Donges, J.F., Loriani, S., Klose, A.K., Abrams, J.F., Alvarez-Solas, J., Albrecht, T., Armstrong McKay, D., Bathiany, S., Blanco Navarro, J., Brovkin, V., Burke, E., Danabasoglu, G., Donner, R.V., Drüke, M., Georgievski, G., Goelzer, H., Harper, A.B., Hegerl, G., Hirota, M., Hu A., Jackson, L.C., Jones, C., Kim, H., Koenigk, T., Lawrence, P., Lenton T.M., Liddy, H., Licón-Saláiz, J., Menthon, M., Montoya, M., Nitzbon, J., Nowicki, S., Otto-Bliesner, B., Pausata, F., Rahmstorf, S., Ramin, K., Robinson, A., Rockström, J., Romanou, A., Sakschewski, B., Schädel, C., Sherwood, S., Smith, R.S., Steinert, N.J., Swingedouw, D., Willeit, M., Weijer, W., Wood, R., Wyser, K., Yang, S. (2025) "The Tipping Points Modelling Intercomparison Project (TIPMIP): Assessing tipping point risks in the Earth system", EGUsphere [preprint], https://doi.org/10.5194/egusphere-2025-1899.

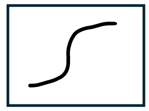
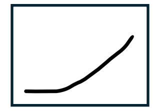
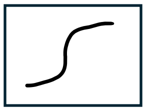
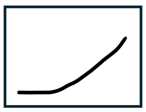
Earth system component (ocean, cryosphere, vegetation–climate, climate–society) exhibiting one or more common tipping traits. Traits are commonly (but not necessarily) exhibited by tipping systems, and systems that may undergo high-impact, unknown-likelihood (HIULs) outcomes, include the ability to undergo shifts that may:

- Be driven by self-amplifying (positive) feedbacks in the system's internal dynamics that become self-sustaining when a critical threshold is crossed due to gradual changes in external forcing or internal dynamics, leading to nonlinear responses.
- Involve system change or acceleration of system change that is abrupt relative to the typical time scale of variability in the system.
- Be irreversible on some specified timescales substantially longer than the time it takes the system to be committed to the shift, where irreversibility may manifest as either rapid or slow change on human timescales.
- Exhibit substantial latency between the time of irreversible commitment and the full realization of large-scale system responses.
- Exhibit deep uncertainty regarding the likelihood and/or magnitude of impacts resulting from tipping dynamics and of involved processes.
- Have plausible pathways to high impact consequences for socioecological systems, potentially including cascading impacts.

Thinking about these in relation to mathematical mechanisms, the key takeaway is that no single mechanism explains all traits; traits emerge from the interaction of system structure, variability, and forcing rates. The mathematical mapping allows us to distinguish uncertainties that are intrinsic to the system's dynamics from uncertainties that are reducible, such as observational gaps or model parameter spread. Due to limitations in the application of these purely-statistical indicator methods on noise and rate induced tipping, an approach based on physical precursors may be beneficial.

Alaa presented the work of the assessment section on "Threshold breaching and tipping points in impacts". In this work the authors identified typologies for categorising climate-socioecological interactions based on whether the climate change driver and/or socioecological response nonlinear or involves threshold behaviour. Four categories were identified (Figure 3).

The risk is dependent on vulnerability and exposure. Distinctions between categories are not always straightforward. Five socioecological systems were assessed: food systems, built environment, health, migration, displacement, mobility, and economy. This built on IPCC WGII AR6 and AR7 report structures and the literature maturity varied, being well-developed for sea level rise socioeconomic impacts but nascent for large-scale migration or displacement thresholds. He provided a framework illustrating the pathways from climate tipping systems to socioecological systems, mediated by exposure and vulnerability.

	Socioecological systems cross a critical threshold or reach a tipping point	**Socioecological systems remain in a (largely) linear response regime**
Climate systems tipping points (TPs) occur	Category A "Cascade" pathways	Category B: "Propagation" pathways
Gradual climate system change	Category C: "Socioecological Thresholds" pathways	Category D: "Incremental" pathways

Figure 3: Typologies for categorising climate-socioecological interactions (WCRP TipSci, in prep[7]).

Alaa outlined that to structure the analysis, the section employs a typology that categorises climate-socioecological interactions based on whether the climate change driver and/or socioecological response is nonlinear or involves threshold behaviour. These categories are:

- Category A ('Cascades'), where a physical tipping point triggers a self-sustaining tipping cascade within the socioecological system;
- Category B ('Propagation'), where impacts from a physical tipping point are severe, potentially crossing coping thresholds, but are ultimately absorbed without triggering a systemic, self-reinforcing shift;
- Category C ('Socioecological Thresholds'), where gradual climate change pushes a socioecological system across its own critical threshold, triggering an abrupt, self-reinforcing reorganisation; and
- Category D ('Incremental') pathways, where impacts scale in a broadly linear and predictable way with the gradual climate driver.

This review focuses on pathways involving non-linear climate and/or socioecological impacts, that are therefore likely to have severe consequences, that is Categories A, B and C (in green in Figure 3 below). It does not assess Category D (in grey) as these fall outside the scope of tipping dynamics.

The narrative flow is as follows: starting with how gradual shifts can trigger threshold effects (Category C), how extreme manifestations or abrupt changes can either propagate (Category B) or

[7] WCRP TipSci (in prep) "High impact climate events, tipping points and irreversible regional impacts: how robust is our understanding?"

induce systemic cascades (Category A) depending on the societal context and underlying vulnerabilities, and how a major climate system tipping point could have catastrophic consequences.

There are some challenges. Conceptual challenges include identifying whether a case falls into the Propagation (B) or Cascade (A) category, which depends entirely on regional context and risk determinants. We cannot assign single-value risk categories. Vulnerability is not static but evolves with accumulating impacts; a threshold that is safe today may be breached tomorrow by the same magnitude event because the underlying coping capacity (governance, resource access) has degraded. There are also synthesis and translation challenges, where the lack of numerical indices used for standard climate impact drivers (CIDs), necessitated qualitative assessments of systemic shifts under deep uncertainty. In addition, literature maturity is highly heterogeneous.

He also highlighted challenges that are beyond the scope of the assessment. Identifying specific strategies that keep impacts within the "Propagation" space (Category B) while acknowledging the hard limits of adaptation where a shift to a self-sustaining "Cascade" (Category A) becomes inevitable. Impacts alter future mitigation capacity and adaptation efforts. Socioecological impacts are not endpoints but active drivers that create feedbacks to the climate system (e.g., ecosystem carbon sink failure). Finally, even if a climatic hazard (a CID) is physically reversible, the associated risk to a socioecological system may not be. The vulnerability and exposure of the system does not necessarily revert.

Audience discussion and Q and A

- It was asked if there could be tipping systems that displayed negative feedbacks (e.g. positive tipping) in the climate system (i.e. "good" outcome). For example warming → more nitrogen released by soils → more productivity.
- Participants asked about the usage of low likelihood / unknown likelihood which was addressed extensively later in the workshop and in the "recommendations" to the IPCC.
- It was suggested changing fire regime could be considered as a more globally encompassing system.
- There were several questions on trying to match theory with empirical evidence as well as spatial and temporal nesting across different Earth System Elements and Systems.
- It was noted that the tipping point literature often stops at physical impacts, but no assessment on potential economic damages, or conflict.
- Alaa responded that in the initial list of socio-ecological systems, they had "peace instability". For the impacts chapter of the WCRP Assessment he explained that they went with WGII-aligned high-level structure. However, peace and stability are considered as part of the underlying societal conditions that affect the vulnerability to impact.
- It was asked why exclude freshwater as a socio-ecological system and Alaa explained this maybe could be covered in the next round.

- It was asked about priorities for the WCRP Assessment and a second question on future/plausible pathway associated with tipping points, and the identification of early warnings.
- Hannah responded that the target is high consequence events, with the aim to constrain uncertainty or ambiguity, and that the science is still in the early stages of development. She noted the aim was not to estimate the global warming level that different elements would tip at.
- It was noted that the WCRP Assessment and the outcomes of the co-sponsored workshop would be an important resource for IPCC, but that IPCC then needed to do its own assessment.
- Participants voted on the mentimeter, largely in favor of revising definitions as an important step (see Figure 4).
- However, views on the proposed framework for understanding how climate Tipping Points translate into socioecological risk were spread.

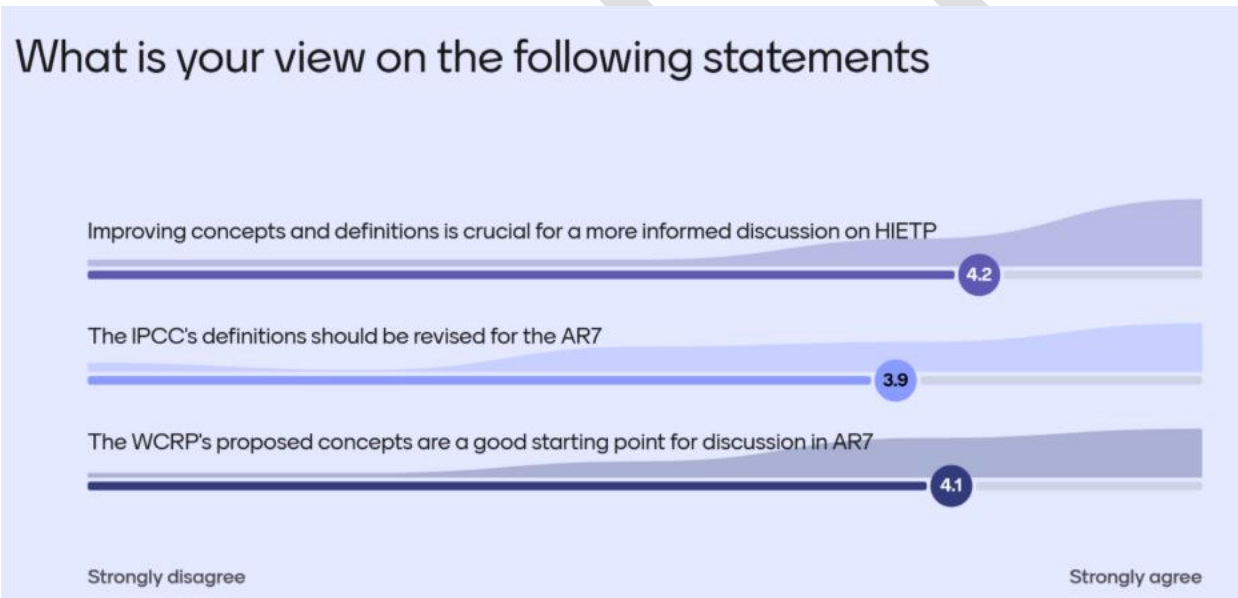


Figure 4: Results of a mentimeter poll on the need to revise IPCC definitions of HIETP.

3.1.4 Summary of WCRP science inputs

14.00 - 15.00	**WCRP Tipping Point Assessment - Lightning talks for systems and knowledge sources** Session Facilitator: Anastasia Romanou (TPA), short inputs by TPA lead authors Ocean - Thomas Frölicher Cryosphere - Ricarda Winkelmann - Brief Q&A Boreal forest and permafrost - Annett Bartsch Tropical ecosystems - Lina Teckentrup - Brief Q&A What can we learn from models and what is missing? - Sabina Abba Omar - Brief Q&A

In this session several lightning talks were given on each of the chapters in the WCRP Assessment Report, by selected Lead Authors to provide the workshop participants with a high level overview, and to highlight areas of non-consensus and consensus, knowledge gaps and priorities for further research.

Thomas Frölicher presented on tipping points and high impact events in several **ocean systems** including Atlantic Meridional Overturning Circulation (AMOC), Sub Polar Gyres (SPGs), Antarctic overturning circulation (AOC), warm water coral, extreme compound events. He focussed on processes, paleo evidence, and consequences. Paleo evidence shows that AMOC collapses have happened during glacial and deglacial periods in the past. Current observations of AMOC strength as well as observational proxies show important interannual to multi-decadal variability, but the record is too short to robustly determine long-term trends. He also noted that CMIP simulations project weakening this century, with collapse unlikely. AMOC collapse is a negative feedback, cools particularly the northern hemisphere, leads to sea-level rise, decrease in ocean carbon uptake, redistribution of net primary production (NPP), and ITCZ shifts southward, leading to drier northern tropics (some of this was based on MIROC AMOC experiments validated against paleo records). He said the chapter team thinks of the SPG as an independent tipping element. SPG can collapse without an AMOC collapse (but not vice versa). Processes are similar to AMOC, on smaller and more localised scale. Paleoclimate evidence links the shift from Medieval Warm Period to Little Ice Age to major SPG weakening. There is observational evidence for strong SPG freshening observed over the last 120 years. Models project episodes of SPG rapid cooling linked to convection collapse. AOC tipping is linked to the Antarctic ice sheet and sea-ice melt, which increases surface freshening and stratification and weakens ocean circulation impacting global overturning circulation. Recent observations are showing weaker dense shelf water formation. Paleoclimate records show past AOC collapses after meltwater pulses. Potential consequences include global cooling, reduced CO_2 uptake, deep-ocean O_2 loss and lower NPP. Other observations include 70% of warm water corals have bleached since 1985 and a further 10-30% drop is expected by 2050.

Ricarda Winkelmann continued the presentations outlining tipping dynamics in the cryosphere, focussing on feedbacks, abrupt and irreversible change and high impact events. This section of the TPA will explore new methodologies and thinking around nested time and spatial scales, interacting feedbacks and risk assessments. For both the Greenland and Antarctic ice sheets there is evidence of irreversible changes on human timescales. Ricarda went on to discuss how we need to leave behind the equilibrium world view when working on tipping dynamics and focus on transient instead of equilibrium response as tipping could be rate-induced as systems, such as some East Antarctic subglacial basins, cannot track the equilibrium response. This rate-induced tipping could be possible even without bifurcation tipping. Other responses could have long response times, for example sea-level changes due to ice sheet and mountain glacier mass loss could be triggered in coming decades, i.e. sea-level commitment, but the response unfolds on longer time scales.

Classical early warning indicators of tipping might fail for long-time scale systems like ice sheets and for rate-induced tipping with small windows for early warnings. This will require reframing the methodology around potential indicators and using broader indicators, such as precursors of abrupt change. An example was given of how hydrofracturing could be a precursor of ice shelf collapse that could lead to ice sheet decline. An indicator for this process could be time intervals during which the production of excess water exceeds the threshold for possible hydrofracturing.

Ricarda finished by discussing moving towards risk assessments and how ice sheet vulnerability could be assessed by combining susceptibility with observed changes. The TIPMIP project also plans to combine different indicators, like likelihood and impacts, to assess risk and distinguish tipping dynamics from gradual change.

After a short Q&A, the program continued with a presentation on tipping dynamics in permafrost and the boreal forest from Annett Bartsch. Permafrost thaw is a process that can be gradual or abrupt with carbon and cloud feedbacks strongly linked to its occurrence. For the carbon feedback increased permafrost thaw and subsequent decomposition releases GHGs into the atmosphere, as such there are signs that the tundra region is becoming a net source of the main GHGs creating a positive feedback. Reduced cloud cover following permafrost thaw can increase surface temperatures leading to further thaw, with this cloud feedback having a similar magnitude to the carbon feedback. Permafrost carbon tipping could be driven by heatwaves, which are increasing in both their frequency and extent in the Arctic. These events impact ground temperature and vegetation leading to a cascade of impacts with soil moisture loss and browning of vegetation leading to forest fire emissions and abrupt permafrost thaw and thaw slumping is triggered. Abrupt thaw processes will increase in the future and contribute an additional 40% to carbon emissions, doubling the global warming impact compared to gradual thaw processes alone. In addition, while gradual permafrost thaw, which can lead to irreversible carbon losses on centennial timescales, is beginning to be represented by ESMs, less progress has been made in including abrupt thaw processes.

The boreal forest is displaying a loss of resilience and there are indications that it is shifting northward with dieback in the south, with this shift expected to occur in the future with more open forest and an increase in fire risk. Increases in forest and peatland fires, linked to heatwaves and drought, could lead to a loss in ecosystem resilience. Annett finished by outlining some of the challenges associated with investigating these processes, including a lack of both satellite and in-situ observations and the loss of data due to geopolitics. Also, ESMs poorly represent or miss key permafrost processes, processes of plant successions and the impact of disturbances.

Annett's talk was followed by a talk from Lina Teckentrup on tipping processes in tropical ecosystems. Climate extremes, such as warming, drought and fires, in different tropical forests can lead to dramatic changes, amplified by complex interactions and feedbacks between vegetation, fires and soils. Several tools can be used to investigate these processes in the past, present and future. ESM experiments show some localised evidence for tipping behaviour, but there is little spatial overlap between different models and the changes are not abrupt. Potential evidence for tipping comes from shifts in the carbon sink and vegetation composition in Amazonia with increases in the frequency and intensity of climate extremes and disturbance. However, other tropical regions appear to be more resilient, however there are fewer observations. There is the strongest evidence for future tipping potential in Amazonia, although the likelihood, timing and scale remain uncertain. Uncertainties also exist around the complex feedbacks in this region and the deforestation-rainfall feedback.

The final talk in the session by Sabina Abba Omar raised the questions of what is missing in ESMs? And what are the challenges and opportunities? Key advantages of ESMs are that they represent the complex system of strongly interacting components of the Earth system, which can capture the dynamics leading to abrupt and rapid changes. More simple models may miss stabilising processes, feedbacks and interactions and ESM are better suited to represent major circulation changes, the influence of extreme events and possible cascading impacts leading to tipping. Challenges for ESMs include limited representation of process and interactions between components, for example ocean eddies and sea ice are not well represented, vegetation dynamics is quite simplistic, and the interaction with Greenland and Antarctic ice sheets is either excluded or limited. Resolution improvements are also needed, along with longer timescales and multiple ensemble members. This will provide benefits such as increased complexity, representation of ocean eddies, coastal currents, deep convective mixing topography and extreme events and a better representation of variability. To achieve this the challenge of computational expense has to be overcome, however, there are opportunities to increase computational efficiency by running components at single precision, using GPUs and developing more effective tuning and spin-up procedures. Machine learning techniques could also be exploited to allow for more complex parametrisation and to update governing equations to improve biases. In addition, hybrid approaches could be adopted using regional climate models and/or stretched or variable grid models depending on the processes being explored and their timescales and the scientific questions being addressed.

The session concluded with comments and Q&A from the audience. It was commented on that when working on tipping points in vastly different systems it is important to define what state the system is tipping towards. The question was asked, why the subpolar gyre (SPG) has not received as much attention as the AMOC and if impact studies on just the SPG exist? It was outlined that it hasn't been widely investigated and often not independently from AMOC collapses. This led to the question of does AMOC collapse cause global or regional sea level rise? It is the case that both can happen, with a global component due to lower heat release alongside a regional North Atlantic component due to dynamical changes.

A clarification was sought on the differentiation of precursors and early warmings as discussed for cryosphere processes. With the response that early warnings are defined in a space with very low forcing, whereas precursors are a broader concept that also applies to rate-induced tipping. A final comment highlighted that local knowledge on aspects such as forest structure could be valuable for the discussion of tropical forests in the Congo Basin. The authors of the section acknowledged that they are aware of this prospect and have been actively trying to engage with scientists from this region but have found it difficult to make contact. In this context, it was also queried why the "tropical ecosystem section" of the TPA was not led by an expert from the Global South, e.g., from the Amazon region.

3.1.5 Summary of World Café

15.15 - 16:45 with coffee	**World Café – Research on HIETPs across Earth system components**: what we know and don't know, what's new, what's coming, what's missing? Moderators: Laura Gallardo, IPCC WGII Vice-Chair, Tim Naish, WCRP Chair Tables were facilitated by SSC members and TPA authors: - Cryosphere (Ricarda Winkelmann) - Atlantic Ocean (Anastasia Romanou) - Southern Ocean (Thomas Fröhlicher) - Tropical Land (ecosystems) (Lina Teckentrup and Laibao Liu) - Boreal ecosystem and high latitudes (Sonia Senerivatne) - Marine and coastal ecosystems (William Cheung) - Atmospheric circulation, monsoons and clouds (Pascale Braconnot) - Tipping in impact systems (Alaa Al Khourdajie) - High impact events beyond "tipping" (Gabriele Hegerl)

The mid-afternoon of Day 1 was dedicated to a "world café style" session with small groups of workshop participants discussing research on HIETPs across Earth system components to address what we know and don't know, what is new, what is emerging, and what may be missing from the current workshop agenda? Facilitated by SSC members and TPA authors, topical tables covered the Cryosphere, Atlantic Ocean, Southern Ocean, Tropical Land (ecosystems), Boreal ecosystems and high latitudes, marine and coastal ecosystems, atmospheric circulation, monsoons and clouds, tipping in impact systems and high impact events beyond "tipping". The aim was to stimulate debate in response to the morning's inputs, and collect insights into the most impactful events, areas of strongest agreement, highest uncertainty, or most controversy, key gaps and relevant new science.

Experts could chose which table to attend and were invited to switch tables after about 40 minutes for a second round. Table facilitators summarized prior discussion for newcomers and agreed on a few key points for the report back at the end of the session. The format provided a platform for rich exchanges, with multiple groups simultaneously discussing similar questions within their topic areas. Many insights and viewpoints were garnered, and key findings around the key questions that were posed re summarised below.

What are the most impactful events?

- AMOC slowdown/decline
- Marine heatwaves
- Freshening of Antarctic bottom water (AABW) and slowdown of Antarctic Overturning Circulation
- Ocean acidification
- Ice shelf collapse
- Sea ice collapse, amplified climate warming, changing ecosystem function
- Shifts in Southern Ocean ecosystem and carbon cycle
- Sea level rise and extreme storm surges
- Contamination of marine food chains affecting resources and health
- Compound events and climate extremes, including rare extremes, impacting society e.g. drought, fire and vegetation
- Permafrost thaw
- Boreal forest fires
- Monsoons
- Shifting mid-latitude Southern Hemisphere circulation

Where is the strongest agreement? (what do we know for sure)?

- For the cryosphere a regional scale focus is better than ice sheet scale
- AMOC will weaken in warmer climate and the impacts of collapse
- Southern Ocean will freshen and uptake heat and AABW formation will be weakened
- Biodiversity will shift and species will migrate from tropical areas
- Tropical coral reef bleaching is the first tipping point
- There is massive uncertainty in modelling tropical ecosystems
- The CIDs framework is a useful mechanism for linking physical events to impacts, but it needs refinement to capture interactions and socio-economic links
- Permafrost thawing will cause warming from carbon release
- Increased risk of forest fire in boreal regions and extension of the forest
- Effects of warming sea water on marine ecosystems and climate-induced shifts in marine biodiversity and species migration

- Rare things are happening – there is an importance to studying tipping points, impacts and HILL events

What is most controversial? Where are the areas of highest uncertainty? Are there key gaps in knowledge?

- AMOC – model uncertainties, observational uncertainty, palaeo evidence is of limited importance
- Compound and cascading events
- Relevant regional and near-term information for impact systems
- Is Antarctic sea ice a tipping element?
- The impact of changing ocean circulation on the carbon cycle
- Terminology and unclear boundaries in definitions
- How close are we to tipping points?
- Impacts and risks on economies and livelihoods. Impacts of positive and negative tipping points have to be clarified.
- High uncertainty for species specific response and community response
- Regional climate responses e.g. precipitation
- Which process triggers tropical ecosystem tipping points?
- Representation of tipping-related processes in models and model uncertainties
- Are boreal forests and boreal permafrost thaw really tipping elements? Why are other forest ecosystems not considered this way?
- Impact of permafrost thaw on greenhouse gas emissions: not a clear understanding of the amount of gas that would be emitted
- Poor representation of forest fire, tree mortality and permafrost processes in Earth system models
- How do you translate the global tipping point framework to regional risk assessments and local vulnerability relevant to policy makers and stakeholders?

What is the most relevant new (emerging) science?

- Building of storylines
- Nested timescales
- Regional dimensions of tipping points
- Modelling of ice-ocean interactions, Antarctic shelf processes and reduction in model biases
- Reassessing confidence in Antarctic sea ice projections
- Extreme events and ability to trigger abrupt change
- Connections and coupling between tipping in tropical ecosystems and other elements
- Use of observations to quantify relevant processes and possibly constraint model representation and processes
- Interaction of tipping points with overshoot scenarios
- Adaption feasibility and feedback: linking impact severity to feasibility of adaptation

- Social systems and the integration of social sciences
- Use of indigenous and local knowledge and community-based research
- Changes in drivers and land-ocean-atmosphere interactions
- High-resolution modelling to resolve processes
- Integration of new processes in models (e.g. nutrient-vegetation-fire feedbacks; role of insects in forest fire impacts
- Effects of Arctic processes on atmospheric circulation

These outcomes were summarised at the start of Day 2 by the session chairs (see 3.2.1). The SSC also used input from the world café tables on issues missing in the programme and areas that required further discussion to refine the topics of the Day 2 BOGs.

3.1.6 Panel discussion - how perspectives on HIETP vary across regions

16:45 - 17.55	**Uptake I: How perspectives on HIETP vary across regions** Moderator: Anna Sörensson, WCRP JSC Live poll with the audience Short inputs by IPCC Bureau Members ● Diana Ürge-Vorsatz (IPCC Vice-Chair, Eastern and Central Europe) ● Laura Gallardo (WGII Vice-Chair, South America) ● Sukumar Raman (WGII Vice-Chair, Asia) ● Aida Diongue-Niang (WGI Vice-Chair, Africa) ● Mark Howden (WGII Vice-Chair, Southwest Pacific) Plenary discussion
17.55 - 18.00	**Closing remarks** Tim Naish, WCRP JSC Chair

Moderator Anna Sörensson, WCRP JSC, started the session by polling the room, with participants responding to four statements by raising either a blue (full agreement), a yellow (some agreement) or a red (disagreement) card.

Statement 1: "High impact events and tipping points are a big "equalizer" of anthropogenic climate change impacts because they leave no region unaffected" received a somewhat mixed vote, but disagreement dominated.

Statement 2: "Where I live and work, no one but scientists knows or cares about tipping points" was also met with scepticism, a majority voted yellow, and yes and no votes were roughly equal.

Statement 3: "Research and communication should focus more on the regional impacts of HIETP to gain attention" evoked a blue wave - strong consensus and support in the room (Figure 5).

Statement 4: "The tipping points discourse distracts and can have detrimental consequences, such as fatalism and anxiety rather than motivate people to act" was met with cautious agreement, a large majority voted yellow, sprinkled with some red and blue votes.

Figure 5: Participants responding to statements during the regional panel discussion.

The moderator then invited short inputs from a panel of IPCC Bureau members representing a focus on Global South countries and economies in transition from within their regions, followed by two solicited statements from the floor, adding the perspective of Arctic Indigenous communities, and Small Island Developing States (SIDS).

All speakers stressed that there was little public or policy discourse on tipping points as they were often perceived as too abstract and academic, too 'distant', not directly policy-relevant and not suited for operational use. It was added that uncertainty especially about triggers and thresholds limits practical use of scientific information.

In contrast, the panelists agreed that media coverage of and attention from policy makers on high-impact climate events, including cyclones (hurricanes etc.) and other storms, heatwaves, coral bleaching, droughts and floods was substantial in many regions. Some regional differences emerged. Sukumar Raman noted a strong focus on heavy precipitation and flooding in South Asia, as well as smoke from forest fires as high impact events potentially linked to changes in large climate phenomena. Mark Howden stated that in the Southwest Pacific, sea level rise presents one of the biggest concerns, but it is seen as neither a tipping point nor a high-impact event due to its ongoing, slow-onset nature. However, he suggested that SLR could be conceptually connected to "distant" tipping point discussions through links such as West Antarctic Ice Sheet instability and its influence on local sea level rise. Laura Gallardo reported rising attention for tipping points in South America due to the alarming developments in the Amazon, and the additional spotlight from the recent Belem COP. For Africa, Aida Diongue-Niang mentioned the existence of several regional tipping points related to monsoon and ecosystems, as well as significant possible impacts from distant tipping dynamics. She emphasized that research and monitoring remained widely under-resourced. She also noted rising attention for high-impact and compound events related to hydrology, alongside emerging studies on a potential tipping point in the Sahelian hydrologic system. Diana Ürge-Vorsatz observed that HIETPs are not a research priority in Central and Eastern Europe (CEE) and lamented the underrepresentation of researchers from that region in the workshop. She added that while a potential AMOC collapse is sometimes debated in CEE, the topic risks being hijacked by denialists as an argument against climate action.

Michael Taylor underscored that for small islands, sea level rise and hurricane intensification behaviour pose existential threats, while marine heatwaves and coral bleaching jeopardize livelihoods. He pointed out that the research community is very small and prioritizes issues related to local impacts and action. Finally, Edward Alexander highlighted the dramatic situation in the circumpolar Arctic, where rapid change in the Yedoma permafrost, including abrupt collapse, and unprecedented wildfires impact local communities and already release substantial amounts of carbon into the atmosphere.

Connecting tipping points to regional consequences and impacts was seen by the panel as the main venue to raise awareness and interest. In terms of communication, 'normal' climate change was perceived as bad enough without having to bring in 'alarming' tipping points. There was also a view that for those who are already on board with climate change, tipping points will make little difference to commitment nor to actions whereas for those with a more denialist perspective, bringing up tipping points is unlikely to raise action.

In the ensuing discussion, the group emphasized agency, regional relevance, and careful language to avoid fatalism while highlighting urgency when communicating climate tipping point research, so it is honest about risks but still empowering, inclusive, and useful for decision making. Several speakers stressed that tipping point messages must be paired with "what to do about it" so people feel agency. Both limits to adaptation, and the negligible influence on emissions in vulnerable least developed countries was clearly stated as a barrier. Participants also underlined dimensions of equity and justice, cautioning against "resilience" language being misused to shift responsibility.

Comments highlighted how media gravitates to catastrophe narratives, which can distort nuance and overemphasize "point of no return" language already popularized in some countries. Context-specific framing that connects to people's lived experience without sensationalizing could be supported by regionalized impact information (e.g., via an Atlas), better engagement with local media and policymakers, and structured products tailored to various audiences. Suggestions included improving framing (e.g. clarity about what is committed vs avoidable, implications for abrupt loss), developing FAQs, fact sheets, and possibly accessible public-facing summaries to convey complex physics and impacts.

The very limited research capacity in the Global South was repeatedly stressed as an important factor when considering priorities. Some called to link global tipping processes to local and regional impacts so communities and adaptation planners can use the information, and more research funding would be directed to HIETP, while serving immediate needs. It was queried whether calls to the research community could address some of the data and research gaps.

3.2 Day 2 – Deep dives, definitions and links to WGII and WGIII

Brief overview of the day

The second day was dedicated to joint work on common definitions and concepts, and to more in-depth discussions of relevant scientific topics, extending the more Earth system focused discussions of day 1 to regional consequences, adaptation and mitigation. The day started with a short mentimeter-poll harvesting impressions from the first day, followed by a summary of the world café outcome by the SSC. Three WG Co-Chairs provided brief reflections before the group split into three breakout sessions, each discussing the same set of IPCC definitions. The after-lunch plenary saw presentations on decision making and governance in the context of HIETP from both an adaptation and a mitigation perspective. The afternoon was then dedicated to two rounds of four parallel breakout groups (BOGs). One group continued discussing and refining the revised concepts and definitions that had come out of the morning session. The other six slots covered topics that had been designed, confirmed or revised by SSC based on the outcome of the discussions on day 1. These addressed the following topics: evidence, methods and tools for HIETP and for their cascades across systems, adaptation and mitigation responses, tipping dynamics in ecosystems, regional events, cascades, and consequences, incl. methods and tools, cascading climate impacts and regional consequences, and carbon cycle feedbacks, with report back scheduled for day 3. The SSC met in the evening to review progress and refine the program for the third and last day.

3.2.1 Kick off day 2 and Co-Chair remarks

09:30 - 10:30	**Kick-off session day 2 -** Facilitator: Laura Gallardo, WGII Vice-Chair Report back from Worldcafé, Feedback on Day 1, SSC-proposal for the afternoon **Brief reflections by Co-Chairs** • Xiaoye Zhang, IPCC WGI Co-Chair • Winston Chow, IPCC WGII Co-Chair • Joy Pereira, IPCC WGIII Co-Chair Introduction to morning BOGs - Robert Vautard, WGI Co-Chair

Figure 6: Word cloud of participant highlights from day 1.

Moderator Laura Gallardo, SSC member and WGII Vice-Chair, and Tim Naish started the first session with a mentimeter poll asking participants to give feedback on their highlights from the first day (Figure 6). They then proceeded to a short synthesis of the worldcafé, recapping the design and the intended workflow from the first collection of inputs and reactions, including what's new, what's missing, and what do we want to add to the program, to in-depth discussion in the afternoon BOGs. In their high-level summary, they addressed the way forward for the issues that had most clearly emerged during day:

- The discussion of the important topic of changing fire regimes and their consequences, as well as the discussion around the role of ocean acidification, specifically whether it would be considered a tipping point or a climate change impact, will be continued both in the BOG on ecosystems, and the one on carbon cycle feedbacks;
- The subtropics, an area covering half of the world's landmass, should be given adequate space across all BOGs;
- Interconnected tipping points, compounding and cascading dynamics would be addressed in both the BOG on evidence, methods and tools for HIETP and for their cascades across systems, and on cascading climate impacts and their regional consequences;
- The question of regionalization, a focus on tipping points vs their impacts on different scales and how that links to relatability would be taken up both in the discussion on concepts and definitions, and in the afternoon BOG on cascading climate impacts and regional consequences.

They then ran a short poll to see the interest for the planned BOGs, which confirmed the very strong interest in the room for regional dynamics and consequences.

Next, three IPCC Co-Chairs provided short reflections on HIETP from the perspective of their respective Working Groups.

Joy Pereira (WGIII Co-Chair) explained how tipping points connect to WGIII through the WGIII mission of inclusivity, integration and impacts:

- Inclusivity: heard this workshop community, tipping points are important! It also is a very political topic, so careful communication is needed.
- Integration: mitigation now (its pace and characteristics) will determine whether we reach these tipping points. What are the implications for cities and settlements along the coasts, for sustainable development, for ecosystems and social systems?
- Impacts: the AR7 wants to deliver actionable key messages, targeted at national governments, subnational governments, businesses, capital markets, NGOs, the media and the public. What are tipping point messages that would drive changes in policies, behaviour and lifestyles?

Winston Chow (WGII Co-Chair):

- Many AR7 adaptation and mitigation authors are participating in this workshop, great success and sign of vision of integration working.
- The science of tipping points needs to be translatable and communicable to all.
- WGII is also delivering a technical guideline on adaptation and vulnerability metrics, trying to make indicators fit for purpose (similar goal to this workshop).
- Take home message from the recent UN Climate Conference COP 30 in Belem: 1.5 °C will be exceeded, and some of these tipping points will come closer to us.

Xiaoye Zhang (WGI Co-Chair):

- Tipping points are very important and deserve a special emphasis in the AR7, and WGI would like recommendations on the WGI/WGII split of this topic.
- Need to enhance everyone's understanding of tipping points. Clearer definitions of the type of events are needed.
- Important aspects of tipping points are their regional dimension, possible cascading impacts, and whether any occurred in the last 10 years or may occur in the next 10 years.
- The considerable uncertainty surrounding the tipping points needs further characterization to avoid over/understatements.

3.2.2 Concepts and definitions workflow

One of the central themes of the meeting was the need to sharpen definitions used to describe high-impact events and tipping points. Participants examined terms such as *abrupt change*, *low-likelihood high impact outcomes, tipping point*, and *cascading impacts,* with the aim of ensuring consistent usage across physical climate science, impacts and adaptation research, and mitigation in AR7.

Participants started from the IPCC definitions of four pre-selected key concepts, for which AR6 glossary entries and definitions already exist. They then examined whether, based on experience since AR6, the practical use of these concepts/definitions had led to unwanted concerns or disagreements within the scientific communities. In this case, it was asked whether a new definition could be proposed. If yes, it was asked what the consensual elements of such a new proposition would be, and what choices should be left for future consideration, for instance by IPCC authors. It was also asked whether new concepts needed to be defined to improve the common understanding. There was a series of breakout groups that allowed all participants to express their views, which were then synthesised. Plenary presentations with opportunities for feedback were made regularly before drafted recommendations were finalized.

The workflow was designed to distil the most important recommendations to IPCC AR7, giving every expert a chance, in small groups, to express its view:

Day 2 BOGI: 3 subgroups working in parallel in 3 different rooms (same questions, work and document for all subgroups)

Day 2 Plenary stocktaking results from BOGI

Day 2 BOGII: one subgroup working on synthesis from BOGI, refining and developing concepts and definitions

Day 2 BOGIII: one subgroup, building on the outcomes of BOGs I and II to provide recommendations for revised definitions and work on proposals for other related concepts

Day 3 Plenary presentation of draft guidance on definitions and framework

Day 3 BOG finalizing drafting of new concepts and definitions, outlining areas of consensus and areas where discussion was still needed

Presentation at the final plenary

3.2.2.1 Summary of BOGI

10.45 - 12.15	**Breakout group phase I – Concepts and definitions** Group I (Robert Vautard, Hannah Liddy) Group II (Ricarda Winkelmann, Aida Diongue-Niang) Group III (Gabriele Hegerl, Narelle van der Wel)

The four concepts that were proposed for analysis were the following, together with the AR6 IPCC definition (IPCC, 2022)[8] and the relevant questions to the participants:

[8] IPCC (2022) Annex II: Glossary [Möller, V., van Diemen, R., Matthews, J.B.R., Méndez, C., Semenov, S., Fuglestvedt, J.S., Reisinger, A. (eds.)]. In "*Climate Change 2022: Impacts, Adaption and Vulnerability*. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Pörtner, H.-O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem, A., Rama, B. (eds.)], Cambridge University Press, Cambridge, UK and New York, USA, pp.2897-2930.

- **Abrupt change**: A change in the system that is substantially faster than the typical rate of the changes in its history.
- **Tipping point**: A critical threshold beyond which a system reorganizes, often abruptly and/or irreversibly.
- **Low-likelihood high-impact outcomes**: Outcomes/events whose probability of occurrence is low or not well known (as in the context of deep uncertainty) but whose potential impacts on society and ecosystems could be high. To better inform risk assessment and decision-making, such low-likelihood outcomes are considered if they are associated with very large consequences and may therefore constitute material risks, even though those consequences do not necessarily represent the most likely outcome.
- **Cascading impacts**: Cascading impacts from extreme weather/climate events occur when an extreme hazard generates a sequence of secondary events in natural and human systems that result in physical, natural, social or economic disruption, whereby the resulting impact is significantly larger than the initial impact. Cascading impacts are complex and multi-dimensional, and are associated more with the magnitude of vulnerability than with that of the hazard (modified from Pescaroli & Alexander, 2015).

Set-up of BOGI: 3 parallel BOGs were located in 3 different rooms, with 4 tables of 4-5 people within each room discussing each one of the 4 concepts. Each concept started with an IPCC Glossary definition as the basis from which the discussion was developed. At each table, participants started to silently work either on sticky notes or directly on the shared online document, to each reflect on the current definitions, followed by discussion time. They exchanged tables during the BOG, after which there was a synthesis of discussion with all BOG participants within each room.

The outcomes of the three groups were synthesized and reported in the plenary. Recommendations and proposed edits showed diversity of views but also some early convergence. Here are the main points for each type:

Abrupt change: issues in the IPCC definition were (i) the reference to “history”, (ii) the vague nature of “substantially” and “typical”. One idea that emerged was to link the definition to the disproportionate nature of the event/change as a response to global warming. New definitions were proposed but no ideal solutions were found.

Tipping point: the current definition was found to emphasize too much one element of a system’s dynamics, and is not directly applicable to an “event”, which can occur after the tipping point. The concepts of temporal/spatial scales, irreversibility, impacts, self-amplifying , abruptness and hysteresis were found important for a revised definition. One group proposed to step away from the focus on the “tipping point” and rather introduce the concept of “tipping dynamics” which is broader. No converging definition was found.

LLHI Outcome: the current definition is not fully meaning what the concept attempts to characterize: the likelihood is generally not “low” but rather “unknown”. The (incorrect) “low-likelihood” (but “unknown” also) probably also has a communication impact that is unhelpful for information. Instead, one of the group proposed to introduce “plausible”, which seems more neutral.

Cascading impacts: several new definitions were proposed, with simpler formulations

Other concepts: It was proposed to provide new definitions for “irreversibility” and to propose concepts of “high likelihood high impact events”

3.2.2.2 BOGII and III definitions and concepts

During BOGII, the discussions continued based on the synthesis of the 3 subgroups of BOGI. Discussions were organized by topics, in a single room, with time for silent writing and time for exchange within and between groups. BOGIII was a continuation of BOGII, with a new group of experts. New definitions were already proposed. An effort was put to summarize the concepts and previous discussions. For each definition, a new definition was proposed, as well as a summary of discussion and the remaining questions and issues to solve. The new definitions were finetuned, but options were left for further agreement (in brackets) and attempt to resolve the issues that were pointed out during the discussions:

Abrupt change: when the system response accelerates suddenly and disproportionately to the level of forcing.

Tipping element/system: A component of the Earth system that undergoes self-reinforcing, abrupt and/or irreversible changes when one or several critical thresholds [tipping points] is crossed.

[Potential/Possible] high impact events: Outcomes or events whose probability is not well known (as in the context of deep uncertainty) but whose impacts would be highly/severely consequential [on regional to global scales].

Cascading impacts: When an event or trend leads to impacts that in turn trigger subsequent impacts.

A proposal for defining **“irreversibility”** in the context of climate change was made:

“A change in a system is irreversible if it does not revert to its initial state under reversed forcing”

3.2.3 Plenary Session: Decision making and governance in the context of HIETP

13.30 – 14.45	**Uptake II: Decision making and governance in the context of HIETP** Moderator: Mark Howden, WGII Vice-Chair **Keynotes** ● Adaptation (Marjolijn Haasnoot, WGII AR6/7 LA)

	● Mitigation (Holly Buck, WGIII AR7 CLA) Plenary discussion

After the brief report back from the morning BOG on concepts and definitions (see 3.2.2.1), session moderator Mark Howden introduced the topic of this plenary session, which was designed to provide space for first reflections on the link to adaptation and mitigation, decision making and governance. He explained that the afternoon BOGs would provide the opportunity to further deepen those considerations.

Marjolijn Hasnoot, WGII AR7 LA, elaborated on challenges and solutions related to adaptation planning and governance in the context of HIETP. In her talk, she noted that adaptation was needed regardless of the degree of uncertainty, for more likely futures and deeply uncertain futures. She outlined different approaches, such as stress-testing, low-regret strategies, robust options and dynamic adaptive pathways, and showcased how in AR6 WGII had dealt with HIETP and deep uncertainty. She highlighted the need for adaptive decision making and monitoring signals informing its design, such as current trends and their implications for future projections, opportunities to learn, time left to adapt, and the progress of adaptation. She presented Dynamic Adaptive Pathways Planning (DAPP) as a method accounting for uncertainties and path dependencies. On interaction between working groups, she addressed alignment on storylines, range of scenarios and uncertainty language, and considering signal lead-response times and adaptation lead times. She highlighted the importance of early warning signals for adaptation, also as an important research gap, along with the effectiveness and limits of adaptation for HIETP.

The following keynote by Holly Buck, AR7 WGIII CLA, queried how the risk of HIETPs might reshape mitigation strategies, starting from three aspects – detecting the tipping point, developing a shared social understanding of its consequences, and researching and implementing rapid mitigation measures. She outlined real world challenges, such as politics and rapid polarization inhibiting the ability to address environmental problems and the long lead times for GHG removal at significant scale. She pointed out that tipping point discourse opens the door to Solar Radiation Modification (SRM), even though SRM would take years to develop as well. She cautioned that “positive tipping points” are a simplistic framework that social scientists from many fields would find reductive. Borrowing “tipping” language in the context of social change would risk confusing people or diluting belief in the physical tipping point concept. Noting that “climate response” may become an umbrella concept in the context of “rapid” or “emergency” measures, she stressed that all of these options are not that rapid in reality, and that such temporalities need to be understood and communicated better. She called for developing a risk-based framing that isn’t going to be dismissed as catastrophism, stressing the agency of IPCC and its authors have in that regard.

During the ensuing Q&A session, participants discussed the role of education, the applicability of the adaptation approaches presented during the talk in a Global South context, mitigation responses to classic TPs like Amazon dieback or AMOC, anticipatory governance and the role of academia and philanthropy, and the role of media in conveying information around HIETP in helpful ways.

3.2.4 Summary of afternoon topical BOGs

15.35 - 16.40	**Breakout group phase II** ● **Evidence, Methods and Tools for HIETP and their cascades across systems** (Anastasia Romanou, Pascale Braconnot) ● **Adaptation and Mitigation responses** (Alaa Al Khourdajie, Laura Gallardo) ● **Tipping dynamics in ecosystems** (Laibao Liu, Sonia Seneviratne)
16.50 – 17.55	● **Regional events, cascades, and consequences, incl. Methods and Tools** (Regina Rodriguez, Pascale Braconnot, Thomas Frölicher) ● **Cascading climate impacts and regional consequences** (Alaa Al Khourdajie, Laura Gallardo) ● **Carbon cycle feedbacks** (Anastasia Romanou, Kirsten Zickfeld)

3.2.4.1 Evidence, methods and tools

Discussions across methods, observations, and modelling highlighted that a wide range of tools exists to study HIETPs, but their application remains limited by fragmentation, non-stationarity, and large uncertainties. Progress is constrained less by the absence of methods than by challenges in integrating multiple lines of independent evidence and interpreting results consistently.

Robust approaches to quantify resilience, detect early-warning signals, and assess proximity to tipping points remain underdeveloped, particularly for complex systems with interacting feedbacks. Early-warning indicators can arise both with and without critical transitions, limiting their predictive value, and therefore we emphasize the need identify proper methods to distinguish false positives/negatives. Non-stationarity further complicates detection and the separation of forced trends from internal variability, especially given short observational records.

Observations are insufficient for many key systems, including permafrost, large-scale ocean circulation (including the AMOC), high-latitude carbon fluxes, fires, and ecosystem dynamics, constraining both direct assessment and model evaluation. The carbon cycle is a major source of uncertainty, particularly regarding potential transitions from sinks to sources.

In modelling, although a hierarchy of tools is available, key processes and feedbacks are often missing or poorly represented, and model resolution is frequently inadequate. More strategic use of idealised, intermediate-complexity, and fully coupled models, combined with improved integration of paleo and observational evidence, is needed.

Overall, the discussions emphasised the need for a common framework to characterise tipping behaviour, improved treatment of uncertainty and non-stationarity, better observational foundations, and fit-for-purpose databases and monitoring systems to advance robust tipping-point assessment.

3.2.4.2 Mitigation and adaption responses

From an adaptation perspective, the “no-regrets” framework is often insufficient for developing countries, where adaptation involves trade-offs between short-term suffering and long-term benefits. Many climate impacts and cascading effects extend well beyond 2100 and may occur rapidly rather than gradually, challenging the temporal framing of current assessments. Policymakers need clearer, more actionable information at national and sub-national scales, as global-level assessments are not always directly usable. Severe events such as the megadrought in Chile illustrate that cascading impacts can exceed adaptation limits even without clearly defined thresholds.

A key recommendation is to better communicate low-likelihood, high-impact risks, including in Summary for Policymakers, by emphasizing impacts rather than only physical phenomena and clearly stating what is known even when timing is uncertain. Stronger integration between physical climate science and impacts research is needed, along with broader geographic representation to avoid regional biases and to better communicate regionally divergent responses.

From a mitigation perspective, long-term and large-scale physical climate changes may affect emissions pathways and the feasibility of mitigation options. Changes in carbon reservoirs, renewable energy potential, energy infrastructure, and carbon dioxide removal could alter carbon budgets and transition pathways. These issues highlight the need for broader analytical frameworks that link climate risks, mitigation feasibility, and sustainable development, and that account for both climate and non-climate perturbations relevant to climate policy.

3.2.4.3 Ecosystems

This breakout group assessed how terrestrial and marine ecosystems may undergo tipping or be strongly impacted by HIETPs, considering key drivers, thresholds, hotspot regions, consequences, and modelling challenges across tropical, boreal, temperate and subtropical ecosystems, as well as marine and coastal systems.

A wide range of ecosystems are potentially affected by non-linear dynamics and tipping behaviour. A big challenge lies in understanding the processes that lead to ecosystem tipping, particularly linear and even nonlinear feedback mechanisms, and to clearly identify tipping dynamics. While quantitative uncertainty remains high, there is high confidence that some ecosystem- and biome-level tipping points exist.

Major uncertainties arise from ecosystem representation in Earth system models, including the use of older land and ocean ecosystem model versions, missing or poorly represented processes (e.g. fire, drought–carbon feedbacks, nutrients, biodiversity), and observational evidence of model shortcomings. Current evidence remains fragmented, with strong regional biases in the literature (e.g., much more literature for the Amazon region than for Asia or Africa) and no systematic global synthesis across ecosystems.

Compound climate events are emerging as critical drivers of ecosystem change, both on land and in the ocean. Changing fire regimes may represent a global-scale tipping risk for terrestrial ecosystems. Species distribution shifts, including poleward and depth migrations, are increasingly important across systems.

Many ecosystems are losing carbon sink capacity or intermittently becoming carbon sources, accompanied by large-scale mortality events in forests and widespread degradation of marine biogenic habitats. Coral reefs and other marine foundation species show clear threshold behaviour with cascading ecological impacts, often with long recovery times.

Non-climatic human pressures—such as land-use change, overfishing, pollution and invasive species—critically reduce ecosystem resilience and interact with climate drivers to amplify tipping risks. Interactions between ecosystem tipping points and other Earth system tipping elements (e.g. large-scale circulation changes) remain poorly understood.

Key research gaps include improved representation of ecosystem processes and disturbances in models, better treatment of compound and scenario-based HIETPs, clearer diagnostics to identify tipping behaviour, improved long-term and deep-ocean observations, and systematic assessment of uncertainty. System scale matters: ecosystem-scale tipping is often expressed through cascading impacts, while biome-scale tipping may involve stronger self-reinforcing feedbacks with implications for the Earth system as a whole.

3.2.4.4 Cascading impacts

Changes in Climate Impact Drivers (CIDs) such as floods or severe storms are often more tangible for societies than abstract tipping points, because they directly affect people, livelihoods, and systems across scales. Cascading impacts propagate through coupled social–ecological systems, accelerating risk and potentially overwhelming coping and adaptive capacities. Cascades can arise from extreme events (e.g., heatwaves, fires, floods) as well as from gradual change that pushes systems beyond context-specific thresholds. Key examples include extreme wildfires producing unaccounted carbon emissions and black carbon, triggering abrupt permafrost thaw and reinforcing regional feedbacks; extreme heat affecting human settlements through health impacts, productivity losses, cooling demand, and inequitable access to adaptation; forest dieback affecting agriculture, fisheries, river navigability, health, and ecosystem services; and cryosphere loss altering freshwater availability with downstream societal consequences. Cascades may also drive behavioural and societal change, including migration, urbanisation, and shifts in technology uptake (e.g., air conditioning after heatwaves).

Limits to adaptation are highly context dependent and often represent soft limits. Cascading impacts can limit adaptation by accelerating risks and overwhelming coping capacity, particularly where impacts escalate faster than responses can be implemented. While adaptation may occur through shifts to different systems, maintaining existing social–ecological systems may no longer be possible in some cases. Certain dimensions—such as people's relationships to land, forests, and ecosystems—may not be adaptable. Cascading impacts can also expose limits to mitigation, for example where fire- and climate-driven ecosystem change reduces carbon sink capacity and constrains the effectiveness of nature-based solutions or carbon dioxide removal, and where land availability or critical mineral constraints limit mitigation options.

Equity and distributional impacts are central. Cascading risks disproportionately affect vulnerable populations and can exacerbate existing inequalities, including gender-based violence under drought or heat stress. Capacity to adapt depends not only on economic resources but also on knowledge transfer, institutions, and local experience, highlighting the importance of Indigenous and local knowledge.

Research gaps and priorities include developing frameworks that explicitly address abrupt and cascading impacts, improving regional and multi-scale analysis, clarifying definitions and reference baselines for cascading impacts, quantifying distributional effects relevant to policy, identifying limits to adaptation and mitigation, and assessing risks of maladaptation and lock-in. There is also a need to better link physical changes to socio-economic outcomes governments care about, such as jobs, affordability, health, and safety.

Open issues for discussion include how to systematically measure cascading behaviour in complex systems, how to distinguish global versus regional thresholds, what constitutes unacceptable maladaptation, and how to better integrate solutions—such as cultural burning and other practices—that can generate positive cascading benefits for climate, biodiversity, food security, and communities.

3.2.4.5 Carbon cycle

In this breakout group, participants assessed the current understanding of how tipping dynamics interacts with the global carbon cycle and the implications for land and ocean carbon sinks, mitigation pathways, and carbon–climate metrics. The group found some evidence that certain tipping elements can affect the carbon cycle, with the strongest indications for the Amazon rainforest, boreal forest systems, permafrost thaw, and to some extent AMOC-related changes. However, uncertainties remain very large regarding the magnitude, timing, and persistence of these impacts. For many of the tipping systems, including for AMOC, there is robust understanding of the impacts, but not necessarily their magnitude, background state dependence and emergence time scales.

The breakout group noted that understanding of compound and cascading effects among tipping elements is extremely limited. Beyond a small number of relatively well-studied systems—most notably the Amazon Rainforest, coral reefs, and kelp forests—there is little evidence on how interactions between multiple tipping processes may amplify or modify carbon cycle responses.

Participants emphasized that interactions between ecosystem-based carbon dioxide removal (CDR) and tipping dynamics are still poorly understood but potentially of high relevance. In particular, there is limited knowledge of how land-based CDR strategies interact with ecosystem resilience and disturbance regimes, and how overshoot and net-negative emissions pathways may influence the likelihood of triggering tipping processes or weakening future carbon removal capacity.

The group identified high uncertainties in carbon cycle modelling related to tipping dynamics. Key processes such as ecosystem responses to drought, fire, permafrost degradation, and other disturbances are insufficiently represented in current Earth system models, and observational constraints remain limited, contributing to substantial structural uncertainty. Coordinated modelling efforts, including TIPMIP, were identified as important for exploring tipping behaviour in emissions-driven frameworks and assessing associated carbon cycle feedbacks.

Finally, the breakout group highlighted that the implications of tipping dynamics for carbon–climate metrics, including TCRE and ZEC, are poorly understood. It remains unclear whether existing carbon budget frameworks adequately capture non-linear, rate-dependent, or potentially irreversible carbon cycle responses associated with tipping points, identifying this as a priority area for future research.

3.2.4.6 Regional events and consequences including methods

The group discussed regional tipping elements, regional consequences of global tipping systems, high-impact events without tipping dynamics, and the spatial dimension of methods and evidence. There was strong agreement that more information is needed on regional impacts of large-scale tipping systems, regional tipping elements with global consequences, interactions and cascades across systems, and regional impacts of high-impact and compound events. Current assessments focus mainly on global tipping systems with regional consequences, while regional tipping leading to global impacts remains poorly understood.

Key challenges include the limited usefulness of multi-model means for tipping behaviour, missing representation of underlying warming trends, lack of quantitative regional estimates, and the risk of misinterpreting regional early-warning signals. Observational and paleo evidence are under used, and regional modelling is constrained by atmosphere only downscaling and delays in applying new global simulations.

Opportunities include targeted large ensemble experiments through CORDEX, closer coordination between TIPMIP and ISIMIP, and greater use of storyline approaches where probabilities are not available, provided they are grounded in published evidence. Embers-type assessments focusing on individual tipping systems could be developed using existing literature.

The group emphasized the importance of non-tipping high-impact events, compound and cascading regional impacts, and the need to rethink "early warning" terminology in favour of indicators or precursors. For future assessments, integrating tipping risks into regional products such as the IPCC Interactive Atlas and identifying missing regional studies through coordinated efforts under WCRP were highlighted as priorities.

3.3 Day 3 – Conclusions, recommendations and communication

Brief overview of the day

The final day of the workshop was dedicated to refining conclusions, writing recommendations, and exploring effective ways of communicating on HIETP. The day started with a report back from the topical afternoon BOGs of day 2. BOG facilitators or rapporteurs each presented key findings, research gaps and priorities, highlighting areas of agreement, convergence or disagreements, challenges and uncertainties, new research and opportunities emerging from community projects, and options for IPCC to address these. The revised definitions and their rationale were presented and discussed. Following a presentation on climate communication, the group split into small teams each drafting a subset of the set of recommendations intended for the IPCC AR7 as well as the broader research community. Participants had the opportunity to change groups as well as to provide mutual feedback during a stocktake plenary around midday. In parallel, four consecutive rounds of the same mini workshop were held, to explore the challenges related to communicating on HIETPs. The meeting closed after a final presentation of the revised definitions and recommendations, and a summary of the communication workshop provided by the facilitator.

Over the weekend, the SSC finalized the summary of conclusions and recommendations document presented to the IPCC authors at the joint LAM1 starting Monday, based on the draft recommendations produced by the workshop.

3.3.1 Presentations and feedback from all BOGs

09.00 – 10.30	**Stocktake plenary** - Moderator Anna Sörensson Key learnings, areas of consensus, and points of divergence: Rapporteurs from topical BOGs to present conclusions Presentation of draft guidance on definitions and framework, Q&A

The morning plenary was dedicated to report backs from the BOGs held on the afternoon of day 2. First, the facilitators of the topical BOGs each provided a short summary of the most important findings of their BOGs (see 3.2.4). followed by a moment for participants to comment or ask clarifying questions. Issues raised by participants during Q&A including:

- Differences in terminology used
- The lack of efficiency in using multi-model/ensemble mean approaches for information on tipping points, since tipping could occur in only one member/model

- Plans to connect TipMIP with ISIMIP, which CIDs might be most relevant in that context, and expected collaboration on the AMOC collapse
- A request to have a definition of HIE that can then be useful for compound extremes, and how to split nature and scale of events in that context
- The need to extend the exploration of regional tipping and regional HIEs connected to regional tipping beyond the current Europe-wide discussions, and expand the scope to other regions globally
- Considering consequences of tipping points as compounding of impacts
- The need to reflect on how these discussions can be brought into an assessment
- Linking between global and regional TPs and their links and scales: WGII authors to determine what conditions lead to tipping events and iterate with WGI about when such conditions occur
- Link with SDGs, CIDs, sustainable development status, mindful that many relevant elements are impacts and not climate drivers
- To what extend tipping points would be driven by a combination of climate and human drivers
- Differentiating between where the tipping happens vs where the impact occur in the regional analysis

Following the report back session for the topical BOGs, the BOG working on concepts and definitions (see 3.2.2) presented a synthesis, including the old definition, the new proposed definition (even if incomplete), and the reasons for change that showed consensus. After the presentation, numerous questions were still raised, pertaining to e.g., "rates of change", the definition of reversibility, the term "forcing" excluding noise-induced change, non-linearity vs. linear change, multiple equilibria, transient vs. equilibrium, providing separate definitions for "tipping elements" vs "tipping point" and the role of a "point" vs “dynamics, how to best convey the tension of high impact but deeply uncertain, and the right level of generality vs climate-specificity.

A last “definitions” - BOG took place in the late morning of Day 3 to finalize the discussions, after which the BOG participants divided in four groups to draft the proposed definitions and describe the history of the discussions for the recommendations document, which can be found in Section 2 of these proceedings. We only describe here the final recommended definitions (with brackets when no consensus is fully reached):

Abrupt change: When the system response accelerates disproportionately to the rate of change of forcing/causes/drivers. [Forcing can include, for instance, changes in atmospheric composition, land use, human systems, etc...]

Tipping element/system: A component of the Earth system that undergoes self-reinforcing changes that are abrupt and/or not reversible on human timescales when a critical threshold is crossed.

"High Impact Potential" (HIP) events or "Potential events with high impacts":
Events whose probability is not well known but whose impacts would be severely consequential on [regional to global] / [large] scales

Cascading impacts: When an event or trend leads to impacts that in turn trigger sequences of impacts across natural and/or human systems.

3.3.3 Recommendations writing

Participants spent the later morning and early afternoon in small groups working in parallel on individual sections of the recommendations and conclusions from the workshop. The groups were distributed across three adjacent rooms, with closely related thematic tables in the same room to enable cross-fertilization and direct feedback. The world café and BOG notes and report back slides were all available online, as were the presentations from WCRP and all other speakers. Each group started from a shared document that already contained the summaries/bullet points from the most relevant sessions. Everyone could access the files of the other groups, to check for redundancy, consistency and provide feedback during writing. The concepts and definitions group continued working on their draft with a slightly larger group, and IPCC Bureau members and SSC helped facilitate the small drafting teams.

The document was structured as follows

1 *Overview*
2 Concepts, definitions, and joint framework
3 Cascades from Earth System HIETPs to impacts, adaptation and mitigation
4 Lines of evidence and methodologies for HIETP
5 Recommendations for WGI
6 Recommendations for WGII
7 Recommendations for WGIII
8 Recommendations across WGs
9 Recommendations for physical climate science research
10 Recommendations for impact, risk and adaptation research
11 Recommendations for mitigation research
12 *Communication workshop summary*

Topic 2, 4, 5 and 9, mostly WGI related, shared one room and topic 3, 6 & 10, 7 & 11 (mostly WGII and III) the other. In a first round, the groups working on recommendations for the specific WGs were asked to also include cross-WG recommendations. In the second round, a few IPCC Bureau members drafted recommendations across WGs (topic 8) based on those notes. Groups 9-11 were tasked to include interdisciplinary research questions and needs in their recommendations.

Each group was given the opportunity to share their key findings or ask for clarification and feedback from the whole group during the stock take plenary at midday, moderated by SSC member Aida Diongue-Niang. There was general agreement in the room on the key issues raised by the drafting groups, and the individual sections were finalised in the afternoon (see Section 2 for the outcome). The communication workshop summary was provided by the facilitator in the direct aftermath of the workshop, and the overview was drafted by the SSC members editing the final document.

3.3.4 Science communication

10.30 - 11.00	**Science communication: Building public trust and respect through effective communication (Sue Escott, Escott Hunt Ltd)** Sue Escott introduced some principles that will guide the afternoon's mini-workshops* on communicating uncertainty and risk, dealing with disagreement, and developing narratives. * The same workshop will be run four times. The smaller groups should give all participants an opportunity to contribute.

In her presentation, Sue Escott elaborated on building public trust and respect through effective communication, stressing that people are more likely to listen to you and act on what you say if you have their trust and respect.

On the issue of HIETP, she emphasized that communication should not be just about explaining the science, but also about its implications for people so that these events are put in context. She highlighted the importance of clarifying definitions, developing a narrative and drawing out key messages, because "tipping point" is used so broadly now, it opens itself to misinterpretation and misunderstanding.

She suggested moving away from the notion of thresholds, which have been confusing, and instead attempt to clarify timescales, noting that "abrupt" feels sudden – a matter of hours or days. She also noted that the way uncertainty is framed impacts on how people react to it: "very small chance of something happening" (=> might happen) being more impactful than "low likelihood of something happening" (=> will probably not happen). She told the audience that deep uncertainty is impossibly challenging for policymakers and underscored that the negative emotions it generates can lead to paralysis.

She explained how communicating differently could generate more positive reactions, by making things relatable, linking the unknowns to actions we can take, and giving an idea of when there may be more certainty. She argued that using tipping points to galvanise action can appear threatening. This is more about helping people to address feelings of hopelessness/helplessness. She reminded us that the key to better understanding is repetition. Hence if messaging to clarify critical information is developed, agreed and shared by multiple experts with multiple audiences over the next few years, people may be better informed when the IPCC reports land and the assessment may be better understood.

She noted that transparency is a way of gaining trust, hence downplaying uncertainty can be damaging in the long term. Scientific disagreement should not be an obstacle to communication. The scientific community should appear united, framing differences as the norm: these are complex issues, science is rarely about absolutes, different researchers take different approaches, etc.

When talking about the risks, she stressed the importance of demonstrating in practical terms that are being taken seriously. Tangible examples are needed to help people understand the risks, and these should be tailored as far as possible to the audience so that they are relatable.

She presented a narrative that makes it easier for non-specialists to take HIETP on board, and explained how it will be explored in the afternoon workshops:

1. Context: what are we talking about here? Why does it matter?
2. Tell me more: what do we know? What is less certain? What are we doing to improve our understanding?
3. What can we do about it? Give hope and offer solutions!

3.3.5 Effective communication workshops

This hour-long workshop used the framework introduced in the morning's presentation to explore various strategies and approaches for effective communication – to see what might work and what won't – both within the research community and for policymakers, the media and other stakeholders. The same set-up was repeated four times and participants were assigned randomly, while ensuring that all drafting groups could continue in parallel.

Each workshop followed the same format:

- Sharing clarification questions and general remarks, responding to the morning's input presentation
- Splitting into three subgroups (of 4-6 participants), each discussing one of the following:
  - ✔ Context and scene-setting
  - ✔ In-depth analysis and individual HIETP
  - ✔ What can we do about it?
- Each group then presenting the main points of their discussion, with feedback from the other tables
- Concluding remarks by the facilitator

Sue Escott did a brief recap of the main lines of discussion during the closing plenary and provided a written summary of the discussions after the workshop that was included in the summary and recommendations document prepared for LAM1 (see Section 2.12).

3.3.6 Final plenary

During the final plenary, participants agreed on the revised definitions as presented by the drafting group. The other recommendations had been widely agreed already during the stock take plenary. Sue Escott, the media professional who had designed and facilitated the communication workshop, then provided a brief overview of its outcome.

In closing, WCRP JSC Chair and SSC Co-Chair Tim Naish expressed his gratitude to all experts, the SSC, his fellow SSC Co-Chair Robert Vautard, the support crew, and in particular Narelle van der Wel and Gerrit Hansen, who had been leading on the workshop management and program development on the WCRP and IPCC sides respectively. He also used the opportunity to thank outgoing WCRP JSC member and past Vice-Chair Pascale Braconnot for her outstanding contribution and service over several decades.

4. Annexes

4.1 Meeting development process and organisation

The decision to jointly hold this workshop as a co-sponsored event was preceded by more than a year of deliberations between the WCRP leadership and the IPCC Co-Chairs, led by WGI. It responded to developments within the WCRP's TPA–process, discussions within the IPCC Bureau (e.g., report from B67) and input from Plenary on the initial plan for an IPCC Expert Meeting or Workshop on the topic (see, IPCC-LXI.Doc.7,Add.1, IPCC-LXII.Doc.8), which were again partly based on inputs by governments calling for a Special Report on Tipping Points during the 7th Assessment Cycle. WCRP leadership and IPCC Co-Chairs deemed the timing of the workshop in the run-up to the first joint LAM as an essential element in enabling the workshops goals, notably strengthening diversity, interdisciplinarity and community engagement, and consensus building in support of WGI Chapter 8 and an integrated approach across IPCC Working Groups. Thankfully, WCRP was in a position to offer leading the workshop in the form of a co-sponsored event, instead of a formal IPCC Expert Meeting, to avoid further delay.

A small organizing group was formed in April 2026 to secure location and venue, refine the concept note and explore options for additional funding. It was decided to hold the meeting at the Jussieu Campus of Sorbonne University in Paris, France, in the last week of November preceding the first IPCC joint LAM, held equally in the Paris metropolitan region. Formal approval for the co-sponsored workshop from the WCRP JSC was obtained in May 2026, including a commitment to provide resources and solicit further funding. A concept note was developed and a formal request to hold a co-sponsored workshop, led by WCRP and adhering to the conditions set out in the principles and procedures of IPCC, was sent to the IPCC Secretariat and accepted in June 2026.

Funding for the meeting, including travel and subsistence support for participants from the Global South, and those who indicated they required assistance, was ultimately secured through a generous contribution by the government of New Zealand, WCRP core funding, the government of France and additional in-kind support from WCRP and the local hosts (IPSL-Sorbonne University, CRNS-INSU).

A Scientific Steering Committee (see Annex 4.2) was formed in June, led by IPCC WGI Co-Chair Robert Vautard, and WCRP JSC Chair Tim Naish, comprising experts from all WGs, both Bureau Members and authors, and lead authors of the WCRP synthesis assessment paper on tipping points (TPA), representing all world regions.

Drawing on prior discussions, the SSC quickly converged on a draft programme, including objectives, outcomes and deliverables. Based on this, they consolidated a first participants list, primarily sourced from authors of the WCRP TPA, all WGI Chapter 8 authors, and other relevant WGI, II and III authors (following their selection at the 69th IPCC Bureau meeting of IPCC) as well as IPCC Bureau members, with an emphasis on balancing both gender and regional representation. Additional experts were considered, to fill important gaps in expertise or geographical representation. Expertise sought included:

- Tipping points and severe events in the ocean, land systems, permafrost, and their impacts including carbon cycling and thresholds in the biosphere;
- Abrupt and large changes in dynamics and modes of variability, monsoon systems, as well as extreme events with large-scale consequences;
- Rapid ice sheet loss and rapid sea level rise;
- Dynamical systems and modelling tools;
- Paleo-evidence, systematic observations and early-warning;
- Societal risks and impacts, including economic impacts, of abrupt climate change and compound events, e.g., risks to food system from severe or multiple events and circulation changes; polycrises; compound risks;
- Decision making and governance in the context of high uncertainty for adaptation and mitigation.

A first batch of invitations was sent end of July, in parallel with the invitations to LAM1 in Paris, enabling IPCC authors and Bureau members attending both meetings to plan their travel accordingly, and to profit from the Trust Fund support for travel, for those eligible, without creating any additional financial implications for IPCC.

The list of participants was finalized in September 2026, with a small number of additional invitations extended to replace last-minute cancellations. The full list of participants can be found in Annex 4.3. Of 65 participants in total (SSC plus invited experts, including 10 IPCC Bureau members), 35 (54%) were women and 26 (40%) were from countries in the Global South or Economies in Transition. The regional distribution (WMO regions) is shown below in Figure 7.

23 experts were affiliated with IPCC AR7 WGI, 12 with WGII and 5 with WGIII. A total of 40 experts had direct links to IPCC AR7, 31 were either authors of the WCRP TPA or otherwise affiliated with WCRP, with a substantial overlap between both groups.

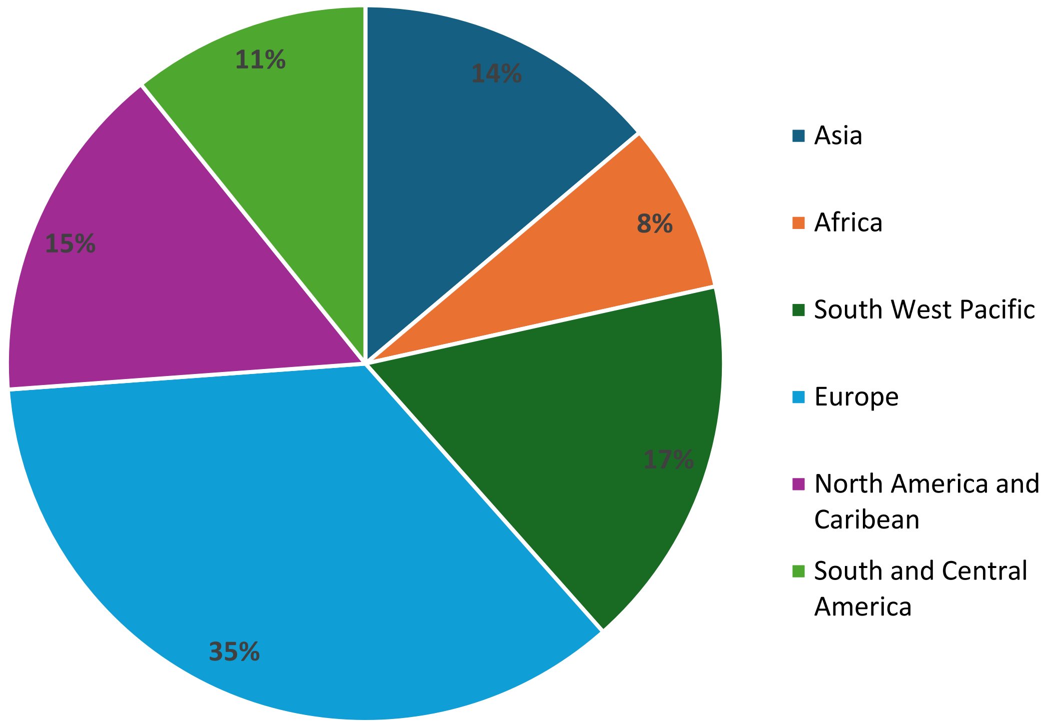


Figure 7: Regional distribution of workshop participants per WMO region.

In early September, the SSC formed a "program subcommittee" for the more detailed discussions on program development and workshop design. The PSC met biweekly and reported to the SSC's monthly meeting, soliciting input in writing on key decisions in between meetings. In parallel, the organising team refined logistical detail on the ground. In the run-up to the meeting, the SSC also shared a collection of recent relevant papers and confidential draft conclusions of the WCRP TPA as background reading.

The Workshop was designed with a workflow from presentations and harvesting scientific evidence [Day 1], to topical deep-dives, exploring cross-WG linkages and building common concepts and definitions [Day 2], to drafting conclusions and concrete recommendations, including on communication [Day 3]. The SSC met each evening to evaluate the progress, adapt or refine the program, and to prepare report backs and agree on summary presentations.

The overall objectives of the workshop included:

- Suggesting consistent terminology and definitions for key concepts, such as tipping points, high impact events, and thresholds.
- Taking stock of the state of knowledge and uncertainties for a range of tipping elements, including in relation to timing, global warming levels, critical thresholds and indications of approaching system transitions.

- Discussing topics that are challenging or lack consensus in the community, in an open and respectful environment.
- Strengthening Global South perspectives on HIETP.
- Identify potential linkages across the three IPCC Working Groups' domains.
- Outline links between severe extreme events, tipping points, and cascading effects.
- Scope what is needed to improve understanding and prediction of tipping points and high impact events.
- Address high uncertainty and related challenges for policy design, including early warning indicators, risk assessment, and science communication.

The main goal was to produce a set of recommendations and conclusions that could directly feed into the first lead author meeting of the IPCC AR7, to support the work of WGI Chapter 8 "Abrupt changes, low-likelihood high impact events and critical thresholds, including tipping points, in the Earth system", and enable a more consistent and integrated approach across chapters and Working Groups on the topic. The workshop was designed to help build consensus and integrate the broad range of existing approaches, perceptions and priorities into a multidisciplinary, comprehensive and inclusive IPCC assessment.

In building the program (see Annex A.4 for the detailed agenda), the SSC incorporated elements that enable more equitable participation, such as silent writing time and structured discussions in small groups, prioritized interactive formats, such as a world café, menti-meter and live-polls, and break-out sessions that often worked by splitting into even smaller groups. The SSC ensured a strong Global South presence among both presenters and facilitators, as well as gender-balance. The latter was more straightforward to achieve, since only 4 of the 13 SSC members were men. The program also included a "regional panel" on the first day giving prominent space for perspectives on HIETP from regions of the world that are traditionally less represented in this research field.

All discussions had designated note-takers, in addition to facilitators and rapporteurs from the group of experts, and notes as well as photos of flipcharts were available for all participants throughout the meeting on a shared online repository. The organizers also set up a slack-space for the workshop to enable quick and direct communication between participants. Each session had a short period reserved at the end for the group to agree on the key issues they wanted to report back, and templates were provided and filled for all sessions. On day 3, the drafting groups for recommendations, led by SSC and IPCC Bureau members, worked from this collection of key findings, but equally profited from the full record of insights gathered throughout the meeting. The drafting groups worked in parallel in adjacent rooms to enable cross-fertilization, and a stock-take plenary provided opportunity to review and feedback across drafting groups. The conclusions from the communications workshops were kindly provided by the facilitator, Sue Escott.

Based on the agreed draft outcomes, the SSC was able to quickly finalize the preliminary workshop summary and recommendations (see Section 2). The existing text was mostly edited for clarity and formatting, and a few redundancies were removed. The final draft was sent to the SSC and all drafting group facilitators for sign-off, before it was distributed to the authors of all three IPCC WGs on the first day of LAM1 and presented during a cross-WG BOG session, led by Bureau Members who had participated in the workshop, on day 2.

The draft proceedings were written and edited based on the notes and report-back templates from the workshop, by the SSC Co-Chairs and a small TSU-WCRP Secretariat team. They were sent to the full SSC and all participants for review (see 4.2 for list of reviewers) before being finalized by the WCRP Secretariat and published online on the WCRP website.

4.2 List of SSC, organizing group, on-site support, reviewers

Scientific Steering Committee

SSC Chairs

Tim Naish, WCRP JSC Chair, New Zealand (Co-Chair)
Robert Vautard, IPCC WGI Co-Chair, France (Co-Chair)

SSC Members

Alaa Al Khourdajie, WCRP TP Assessment / AR7 WGIII LA, Syria/UK
Pascale Braconnot, WCRP JSC / Local host, France
Aida Diongue-Niang, IPCC WGI Vice-Chair, Senegal
Laura Gallardo, IPCC WGII Vice-Chair, Chile
Gerrit Hansen, IPCC WGI TSU, Germany/France
Gabriele Hegerl, WCRP SLC / WCRP TP Assessment, WGI AR7 LA, UK
Laibao Liu, WCRP TP Assessment, China
Anastasia Romanou, WCRP TP Assessment / AR7 WGI CLA, USA
Sonia Seneviratne, IPCC WGI Vice-Chair, Switzerland
Anna Sörensson, WCRP JSC / WCRP IPCC Focal Point, Argentina
Narelle van der Wel, WCRP Secretariat - TPA point, New Zealand/Switzerland
Ricarda Winkelmann, WCRP TP Assessment / TIPMIP / WGI AR7 LA, Germany

Organizing group

Pascale Braconnot, WCRP JSC / LSCE-IPSL, France
Gerrit Hansen, IPCC WGI TSU, Germany/France
Catherine Michaut, LSCE-IPSL, France
Tim Naish, WCRP JSC Chair, New Zealand
Robert Vautard, IPCC WGI Co-Chair, France
Narelle van der Wel, WCRP Secretariat - TPA point, New Zealand/Switzerland

On site scientific and technical support

Catherine Michaut, LSCE-IPSL, France
Giovanni Chellini, LSCE-IPSL, Italy/France
Peter Abbott, WCRP Secretariat/WMO, UK/Switzerland
Michael Westphal, IPCC WGIII TSU, USA/Germany
Emilie Vanvyve, IPCC Chair's office, Belgium/UK
Yona Silvy, IPCC WGI TSU, France
Carlos Montoya, WCRP Secretariat/WMO, Colombia/Switzerland

Reviewers (in alphabetical order)

Alaa Al Khourdajie, Ana Bastos, Pascale Braconnot, Holly Buck, Winston Chow, Mastawesha Misganaw Engdaw, Sue Escott, Thomas Frölicher, Nick Golledge, Celine Guivarch, Gabriele Hegerl, Mark Howden, Charlie Koven, David Lapola, Laibao Liu, Virna Meccia, David Obura, Joy Pereira, Anastasia Romanou, Anna Sörensson, Thomas Stocker, Diana Ürge-Vorsatz, Michael Westphal, Zelina Zaiton Ibrahim.

4.3 List of participants

Last Name	First Name	Affiliation	Country [of origin/affiliation]
Participants			
ABBA OMAR	Sabina	University of Cape Town	South Africa
ABE OUCHI	Ayako	University of Tokyo	Japan
ABRAM	Nerilie Jane	The Australian National University	Australia
AL KHOURDAJIE	Alaa	Imperial College London	Syria/United Kingdom
ALEXANDER	Edward	Woodwell Climate Research Centre	USA
ARIAS	Paola	Universidad de Antioquia	Colombia
BARTSCH	Annett	B.GEOS	Austria
BASTOS	Ana	University Leipzig	Portugal/Germany
BETTS	Richard	Met Office Hadley Center	United Kingdom
BRACONNOT	Pascale	LSCE-IPSL	France
BUCK	Holly	University of Buffalo	USA
CARNICER	Jofre	University of Barcelona	Spain
CASSOU	Christophe	LMD-IPSL	France
CHEN	Yang	Chinese Academy of Meteorological Sciences	China
CHEUNG	William	University of British Columbia	Canada
CHOW	Winston	Singapore Management University - IPCC WGII Cochair	Singapore
COLLEONI	Florence	National Institute of Oceanography and Applied Geophysics	Italy
DECONTO	Rob	University of Massachusetts	USA
DEMIREL	Nazli	Istanbul University	Türkiye
DIONGUE NIANG	Aida	National Agency for Civil Aviation and Meteorology - IPCC WGI Vice Chair	Senegal
ENGDAW	Mastawesha Misganaw	Alliance of Biodiversity International and CIAT	Ethiopia
FRIEDLINGSTEIN	Pierre	University of Exeter	United Kingdom
FRÖLICHER	Thomas	University of Bern	Switzerland
GALLARDO	Laura	University of Chile - IPCC WGII Vice Chair	Chile
GAYE	Amadou	University Cheikh Anta Diop	Senegal
GOLLEDGE	Nicholas	Victoria University of Wellington	New Zealand
GUIVARCH	Céline	Ecoledes Ponts, Institut Polytechnique de Paris	France
HAASNOOT	Marolijn	Deltares	Netherlands
HANSEN	Gerrit	IPCC WGI TSU	Germany/France
HEGERL	Gabriele	University of Edinburgh	United Kingdom

HEIL	Petra	British Antarctic Survey	United Kingdom
HOWDEN	Mark	Australian National University - IPCC WGII Vicechair	Australia
IFO	Suspense Averti	Marien Ngouabi University, Brazzaville	Republic of the Congo
ISLAM	A.K.M. Saiful	Bangladesh University of Engineering & Technology	Bangladesh
JAIN	Shipra	University College London	India/United Kingdom
KOVEN	Charles	University of California	USA
LAPOLA	David	UNICAMP	Brazil
LIDDY	Hannah	Columbia University	USA
LIU	Laibao	The University of Hong Kong	China
MECCIA	Virna Loana	CNR-ISAC	Argentina/Italy
MOISE	Aurel	Meteorological Service Singapore	Singapore
NAISH	Tim	Victoria University of Wellington	New Zealand
NOWICKI	Sophie	University of Buffalo	United States
PATHAK	Minal	Ahmedabad University	India
PEREIRA	Joy	Universiti Kebangsaan Malaysia - IPCC WGIII Cochair	Malaysia
RODRIGUES	Regina	Federal University of Santa Catarina	Brazil
ROMANOU	Anastasia	Columbia University	USA
SENEVIRATNE	Sonia	ETH Zurich - IPCC WGI Vicechair	Switzerland
SILVANO	Alessandro	University of Southampton	United Kingdom
SÖRENSSON	Anna	National Scientific & Technical Research Council of Argentina	Argentina
STOCKER	Thomas	University of Bern	Switzerland
SUKUMAR	Raman	Indian Institute of Science - IPCC WGII Vicechair	India
TAYLOR	Michael	University of West Indies	Jamaica
TECKENTRUP	Lina	Barcelona Supercomputing Centre	Germany/Spain
URGE-VORSATZ	Diana	Central European University - IPCC Vice Chair	Hungary
VAN DER WEL	Narelle	WCRP Secretariat	New Zealand/ Switzerland
VAUTARD	Robert	LSCE-IPSL - IPCC WGI Cochair	France
VILLEGAS	Juan Camilo	Universidad de Anitoquia	Colombia
WINKELMANN	Ricarda	Max Planck Institute / PIK	Germany
WREFORD	Anita	Lincoln University	New Zealand
XIAO	Cunde	Beijing Normal University	China
YANG	Shuting	DMI	Denmark
ZAITON IBRAHIM	Zelina	Universiti Putra Malaysia	Malaysia

ZHANG	Xiaoye	Chinese Academy of Meteorological Sciences IPCC WGI Cochair	China
ZICKFELD	Kirsten	Simon Fraser University	Canada

On site science and technical support			
ABBOTT	Peter	WCRP Secretariat/WMO	UK/Switzerland
MICHAUT	Catherine	IPSL	France
CHELLINI	Giovanni	LSCE-IPSL	Italy/France
MONTOYA	Carlos	WCRP Secretariat	Columbia/Switzerland
SILVY	Yona	IPCC WGI TSU	France
VANVYVE	Emilie	IPCC Chair's office	Belgium/UK
WESTPHAL	Michael	IPCC WGIII TSU	USA/Germany

Guests and external speakers			
BOREL	Corinne	Ministry of Higher Education and Research of France	France
CHIRIACO	Marjolaine	Ministry of Higher Education and Research of France	France
COANTIC	Amélie	Ministry for the ecological transition CGDD	France
GODIN BEEKMANN	Sophie	IPSL	France
OBURA	David	IPBES Chair	Kenya
PALMER	James	Ministry for the Environment of New Zealand (Recorded presentation)	New Zealand
SCHWOOB	Marie Hélène	Ministry for the ecological transition CGDD/SRI/SDR	France
ESCOTT	Susan	Escott Hunt Ltd	United Kingdom

4.4 Agenda of the meeting

WCRP/IPCC Co-sponsored Workshop on Earth System High Impact Events, Tipping Points and their Consequences (HIETP)

26-28 November 2025, Sorbonne University Paris, Jussieu-Campus

Rooms:

	26 Nov	Esclangon Building
	27 Nov	Plenary Amphi 25
	28 Nov	Plenary Tour Zamansky 24th Floor, room 2400
	27+28 Nov	Other rooms to be announced in Tour Zamansky and Tour 45

DAY 1	
08.15 - 09.00	**Registration - Esclangon Building Hall**
09.00 - 10.00	**Opening Session** - Moderator: Pascale Braconnot, WCRP JSC **Welcome addresses by the hosts** ● Sophie Godin-Beekmann, Director L'Institut Pierre-Simon Laplace - IPSL and Sorbonne University ● Corinne Borel, Ministry of Higher Education and Research, France ● Marie-Hélène Schwoob, Ministry for Ecological Transition, CGDD, France ● James Palmer, Ministry for the Environment of New Zealand (videomessage) **Introduction and vision for the workshop** (Tim Naish, WCRP Chair, Robert Vautard, WGI Cochair)
group photo and coffee	
10.30 - 12.00	**Overview and critical appraisal of High Impact Events and Tipping Points (HIETP) in global scientific assessments** Moderator: Tim Naish, WCRP Chair **Kick-off survey on concepts and perceptions** (Robert Vautard, IPCC WGI Chair) **Keynotes and exchange** ● IPCC WGI (Thomas Stocker, AR5 WGI Cochair) ● IPCC WGII (Zelina Zaiton Ibrahim, AR6/AR7 WGII CLA) ● IPBES (David Obura, IPBES Chair)
lunch	

13.00 - 14.00	**WCRP Tipping Point Assessment - Overview panel on framing, concepts, and challenges** Session Facilitator: Gabriele Hegerl, WCRP TPA lead, inputs by TPA lead authors Rationale and Key Questions (Gabriele Hegerl) Learnings on definitions, scope and framing (Hannah Liddy) Challenges with conceptualizing "high impact/threshold events" from the impacts side (Alaa Al Khourdajie) Q&A and discussion
14.00 - 15.00	**WCRP Tipping Point Assessment - Lightning talks for systems and knowledge sources** Session Facilitator: Anastasia Romanou (TPA), short inputs by TPA lead authors Ocean - Thomas Frölicher Cryosphere - Ricarda Winkelmann ● Brief Q&A Boreal forest and permafrost - Annett Bartsch Tropical ecosystems - Lina Teckentrup ● Brief Q&A What can we learn from models and what is missing? - Sabina Abba Omar ● Brief Q&A
coffee	
15.15 - 16:45 with coffee	**World Café – Research on HIETPs across Earth system components**: what we know and don't know, what's new, what's coming, what's missing? - Moderators: Laura Gallardo, IPCC WGII Vicechair, Tim Naish, WCRP Chair Small group discussions in "world café style" around nine tables, responding to prior presentations and collecting insights on the most impactful events, areas of strongest agreement, highest uncertainty, or most controversy, key gaps and relevant new science. Participants are invited to switch tables at halftime, to open additional/alternative topical tables, and provide input for the Day 2 program. Each group will be asked to produce a report back slide capturing key findings. Tables will be facilitated by SSC members and TPA authors for the following topics: ● - Cryosphere (Ricarda Winkelmann) ● - Atlantic Ocean (Anastasia Romanou) ● - Southern Ocean (Thomas Fröhlicher) ● - Tropical Land (ecosystems) (Lina Teckentrup and Laibao Liu) ● - Boreal ecosystem and high latitudes (Sonia Senerivatne)

	- - Marine and coastal ecosystems (William Cheung and Aida Diongue-Niang) - - Atmospheric circulation, monsoons and clouds (Pascale Braconnot) - - Tipping in impact systems (Alaa Al Khourdajie) - - High impact events beyond "tipping" (Gabriele Hegerl)
16:45 - 17.55	**Uptake I: Panel discussion – How perspectives on HIETP vary across regions** Moderator: Anna Sörensson, WCRP JSC Live poll with the audience Short inputs by IPCC Bureau Members - Diana Ürge-Vorsatz (IPCC Vicechair, Eastern and Central Europe) - Laura Gallardo (WGII Vicechair, South America) - Sukumar Raman (WGII Vicechair, Asia) - Aida Diongue-Niang (WGI Vicechair, Africa) - Mark Howden (WGII Vicechair, South West Pacific) Plenary discussion
17.55 - 18.00	**Closing remarks** Tim Naish, WCRP Chair
	break
20.30 - 23.15	**Social Event: Dinner cruise on the Seine**
	DAY 2
09:30 - 10:30	**Kick-off session day 2 -** Facilitator: Laura Gallardo, WGII Vicechair Report back from Worldcafé, Feedback on Day 1, SSC-proposal for the afternoon (Laura Gallardo, Tim Naish) **Brief reflections by Co-Chairs** - Xiaoye Zhang, IPCC WGI Co-chair - Winston Chow, IPCC WGII Co-chair - Joy Pereira, IPCC WGIII Co-chair Introduction to morning BOGs - Robert Vautard, WGI Cochair
	coffee
10.45 - 12.15	**Breakout group phase I – Concepts and definitions** Group I (Robert Vautard, Hannah Liddy): Tour 45/55 - IPSL201 Group II (Ricarda Winkelmann, Aida Diongue-Niang): Tour Zamansky TZ 2307 Group III (Gabriele Hegerl, Narelle van der Wel): Tour Zamansky TZ 2402
	lunch
13.30 – 14.45	**Overview of results from BOGI** (BOGI Facilitators)

	Uptake II: Decision making and governance in the context of HIETP - Moderator: Mark Howden, WGII Vicechair **Keynotes** ● Adaptation (Marjolijn Haasnoot, WGII AR6/7 LA) ● Mitigation (Holly Buck, WGIII AR7 CLA) Plenary discussion Confirmation of rooms and facilitators for afternoon BOGs and sneak preview day 3
coffee	
15.35 - 16.40	**Breakout group phase II** Rooms tbd: TZ 2402, TZ 2307, Tour 45/55 - IPSL201, LOCEAN - Tour 45/55, Room 417, LATMOS - Tour 45/46 - 411 tbd a. **Concepts and definitions - synthesis** (Robert Vautard, Gabriele Hegerl) This BOG will work on synthesizing the outcome of BOGI and on further refining and developing concepts and definitions b. **Evidence, Methods and Tools for HIETP and for their cascades across systems I** (Anastasia Romanou, Pascale Braconnot) The BOG will characterize different lines of evidence and methodologies used for HIETP identification, classification, trait attribution, early warning signal definition, cascading risk assessment and implications for equilibrium and transient climate sensitivity assessments. It will combine input and perspectives from all IPCC working groups. c. **Adaptation and Mitigation responses** (Alaa Al Khourdajie, Laura Gallardo) This is the first BOG designed to bridge the gap between the physical science of tipping points and their societal and ecological implications, and understanding their consequences. A key focus is understanding how changes in temperature, precipitation, sea level, extreme events, etc. (Climatic Impact-Drivers (CIDs)), transmit tipping point effects from the climate system to socioecological systems. It will address the direct implications for climate strategy (adaptation and mitigation). d. **Tipping dynamics in ecosystems** (Laibao Liu, Sonia Seneviratne) Discuss ecosystems and how they might be a) tipping and b) impacted by HIETPs in the physical system, including the key drivers and processes, critical environmental thresholds, hotspot regions, consequences, modelling challenges and uncertainties, etc
16.50 – 17.55	**Breakout group phase III** Rooms tbd: TZ 2402, TZ 2307, Tour 45/55 - IPSL201, LOCEAN - Tour 45/55, Room 417, LATMOS - Tour 45/46 - 411 tbd a. **Concepts, definitions, and framework - guidance for AR7** (Robert Vautard, Gabriele Hegerl) Building on the outcomes of BOGI and II, this session will draft recommendations for revised definitions of the four initial concepts and work on proposals for other

	related concepts, providing either draft definitions or options / directions for adapting the current IPCC definitions and a consistent use of terminology across working groups. b. **Regional events, cascades and consequences, incl. methods and tools** (Regina Rodriguez, Pascale Braconnot, Thomas Frölicher) This BOG will focus on the regional aspects of Earth System HIETP - regional events, regional irreversible shifts, cascading effects from global events, and elaborate on different lines of evidence, tools and methodologies used in this context. c. **Cascading climate impacts and regional consequences** (Alaa Al Khourdajie, Laura Gallardo) This is the second BOG designed to bridge the gap between the physical science of tipping points and their societal and ecological implications, and understanding their consequences. A key focus is understanding how changes in temperature, precipitation, sea level, extreme events, etc. (Climatic Impact-Drivers (CIDs)), transmit tipping point effects from the climate system to socioecological systems. It will take a look at the fundamental behaviour of socioecological systems when faced with these pressures. d. **Carbon cycle feedbacks** (Anastasia Romanou, Kirsten Zickfeld) This BOG will discuss the links between HIETP and the carbon cycle, how well we understand potential consequences of HIETP for the global land and ocean carbon sinks, and implications for related concepts such as the TCRE assessment. It will examine potential feedback mechanisms, including the role of cascading impacts and potential implications of different emissions pathways (e.g., overshoot) and mitigation strategies, seeking input from all three WGs.	
DAY 3		
09.00 – 10.30	**Stocktake plenary** - Moderator Anna Sörensson Key learnings, areas of consensus, and points of divergence: Rapporteurs from BOGsII and III b-d/e to present conclusions Presentation of draft guidance on definitions and framework (BOGII+III a)	
10.30 - 11.00	**Science communication: Building public trust and respect through effective communication (Sue Escott, Escott Hunt Ltd)** Sue Escott will introduce some principles that will be guiding the afternoon's mini-workshops* on communicating uncertainty and risk, dealing with disagreement, and developing narratives. * The same workshop will be run four times. The smaller groups should give all participants an opportunity to contribute.	
Coffee		
11.15 – 12.30	**Breakout group phase IV (TZ 2402, 2307)** Drafting groups for guidance	**Effective Communication Workshops (Tour 45/55, IPSL Room 201)** Their uncertainty, risks and potential consequences make HIE/TPs one of the greatest communication

<table>
<tr><td colspan="2">lunch</td><td rowspan="3">challenges faced by climate scientists. The stakes are high, views tend to be strong, and communication is not straight forward.
This hour-long workshop* will use the framework introduced in the morning's presentation to explore various strategies and approaches for effective communication – to see what might work and what won't – both within the research community and for policymakers, the media and other stakeholders.</td></tr>
<tr><td>13.45 – 14.15</td><td>Stocktake plenary - Moderator Aida Diongue-Niang</td></tr>
<tr><td>14:15 – 15.30</td><td>Breakout group phase V (TZ 2402, 2307)
Drafting groups for guidance, conclusions, and summary slides</td></tr>
<tr><td colspan="3">coffee</td></tr>
<tr><td>16.00 – 17.30</td><td colspan="2">Final plenary - Moderator Tim Naish
Presentation of draft guidance and conclusions
Summary presentation of communications workshop
Closing of the session</td></tr>
</table>

4.5 Acronyms

AMOC	Atlantic Meridional Overturning Circulation
AR	Assessment Report (of the IPCC)
AR5	5th Assessment Report of the IPCC
AR6	6th Assessment Report of the IPCC
AR7	7th Assessment Report of the IPCC
CDR	Carbon Dioxide Removal
CID	Climatic Impact Driver
CLA	Coordinating Lead Author
CORDEX	Coordinated Regional Downscaling Experiment
ECV	Essential Climate Variable
ESM	Earth System Model
FAR	First Assessment Report of the IPCC
GHG	Greenhouse Gas
HIETP	High Impact Events and Tipping Points
HIP	High Impact Potential
HILL	High Impact Low Likelihood
HIUL	High Impact Unknown Likelihood
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
ISIMIP	The Inter-Sectoral Impact Model Intercomparison Project
LAM1	First Lead Author Meeting
LLHI	Low-Likelihood High Impact
ML	Machine Learning
RCM	Regional Climate Model
SD	Sustainable Development

SDG	UN Sustainable Development Goals
SLR	Sea level rise
SSC	Scientific Steering Committee
SPM	Summary for Policymakers
SRM	Solar Radiation Modification
TCRE	Transient Climate Response to cumulative CO_2 Emissions
REB	Remaining Emissions Budget
TIPMIP	The tipping points model intercomparison project
TP	Tipping point
TPA	WCRP Tipping Point Assessment
TS	Technical Summary
WCRP	World Climate Research Programme
WGI	Working Group I of the IPCC - The physical science basis
WGII	Working Group II of the IPCC - Impacts, Adaptation and Vulnerability
WGIII	Working Group III of the IPCC - Mitigation
ZEC	Zero Emissions Commitment